SPECIFICITY AND VARIABILITY OF PRACTICE IN A RAPID AIMING TASK

By

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SPECIFICITY AND VARIABILITY OF PRACTICE
IN A RAPID AIMING TASK

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The nature of practice has long been studied due primarily to its significance in learning and performance. The specificity of learning effect is when withdrawing or adding a significant amount of afferent information after a period of practice results in a deterioration of performance. Although research has told us how much specificity is needed to elicit the effect, little research has been done on the limits or causes of this effect. The purpose of the first experiment was to determine how much variability is necessary to compensate for the poor performance caused by the specificity of learning effect. Volunteers (N=60) from the University of North Dakota were placed in groups with various percentages of 200 acquisition trials being with or without vision of a cursor during an aiming task. A SummaSketch graphics tablet, computer, and manual-aiming program

were used with vision and non-vision groups performing 200 acquisition trials and a 20 trial transfer task. A 4 (Condition) X 11 (Block) ANOVA with repeated measures on the last factor revealed several findings. Movement time remained constant during the experiment, and a learning effect was demonstrated as expected. The specificity of learning effect was replicated; 25% (and only 12.5% in one case) variability was sufficient to overcome the negative effects on performance caused by the specificity of learning effect in both the vision and non-vision transfer groups. The second experiment focused on determining dynamic vision's (vision of movement) role in the specificity of learning effect. Volunteers (N=40) were placed in groups performing 200 or 40 trials of an aiming task with or without the benefit of kinetic vision (vision of the cursor or the hand and arm). A Condition (4) X Block (11) ANOVA with repeated measures showed both a learning effect as well as the specificity of learning effect. Also, kinetic vision had a powerful influence on performance and the specificity of learning effect.

CHAPTER 1
THE SPECIFICITY OF LEARNING HYPOTHESIS

Introduction

The Specificity of Learning Effect

The nature of practice has long been studied due primarily to its significance in learning and performance. Recently, a renewed interest in the notion of specificity of learning has been evident in the literature. These studies have resulted in the extension of the original idea of specificity of learning, that performance on one task is not useful for predicting performance on other tasks (Henry, 1968), to the more comprehensive idea that learning and subsequent performance are specific to the conditions in which practice occurs (e.g., Proteau, Marteniuk, & Levesque, 1992). When people practice with a specific set of afferent information (i.e., information coming from one of the senses such as sight, sound, or touch), there is a distinct specificity of learning effect (Adams, Gopher, & Lintern, 1977; Proteau, Marteniuk, Girouard, & Dugas, 1987). Adams et al. (1977), using visual afference to demonstrate the specificity effect, proposed that visual information becomes even more important in motor control after extensive practice. Proteau et al. (1987) found that the addition of visual information regarding an ongoing movement caused a significant error increase for participants who had practiced without it and vice versa. Proteau and Cournoyer (1990) added to knowledge on the specificity effect by proposing that

practicing a specific task results in a representation consisting of an integration of all relevant information of a movement task and that this representation becomes more tightly integrated with increased practice. The specificity of learning hypothesis is summed up succinctly by Proteau (1992), who stated that withdrawing or adding a significant amount of afferent information after a period of practice, where it was respectively present or absent, results in a deterioration of performance.

To date, there has been much research on the specificity of learning hypothesis but relatively little on its limits or causes (Proteau et al., 1992). The transfer paradigm appears to have been the best way to study vision's role in the specificity of learning for the past few decades (Annett, 1959; Johnson, 1980; Smyth 1977; 1978; Temprado, Vieilledent, & Proteau, 1996) and it has been used to determine that there is indeed a specificity of learning effect (Adams, Goetz, & Marshall, 1972; 1977; Proteau, 1992; Proteau & Cournoyer, 1990; Proteau, Marteniuk, Girouard, & Dugas, 1987). This specificity of learning effect may be due to the building of a strong multi-modal representation that causes performance to suffer when the representation is not matched in the task requirements (Proteau et al., 1992). For example, if vision were to be efficiently used, relevant information from this modality would have to be incorporated into the sensorimotor store for the task. In this case, the addition of vision probably resulted in the participants attending to it and neglecting the basis on which the task had been learned because of its dominance as a source of information (Proteau et al., 1992).

Thus, how strong is the specificity of learning effect? Can it be altered or affected by some mediating factor? The purpose of this dissertation was to test the limits of the specificity of learning effect with regard to variability and to discover how much variability was required to negate the deleterious effects that it has on outcome when the task was performed with different afferent conditions.

Although research has given us a clue as to how much specificity is needed to promote the appearance of a negative effect with respect to vision (Elliot & Jaeger, 1988; Proteau, 1992; Proteau & Cournoyer, 1990; Proteau et al., 1987), little is known about the limits of the specificity of learning effect. The number of trials taken to elicit the specificity effect has not been directly studied but the limits can be surmised by the many studies that have looked at the specificity of learning effect. Elliott and Jaeger noticed the effect after only 70 trials of a manual aiming task while it has been reliably found to appear after 150 (Adams, 1972; Proteau & Cournoyer, 1990), 160 (Proteau, 1992), 165 (Proteau & Marteniuk, 1993) and 200 trials (Proteau et al., 1987; Proteau & Marteniuk, 1993; Proteau et al., 1992). It is also evident that the more trials that are performed, the stronger the specificity effect (Proteau, 1992; Proteau et al., 1987; Proteau et al., 1992; Proteau & Marteniuk, 1993). In addition, research shows the number of trials that were not enough to elicit the effect. No specificity effect was found for 15 (Adams, 1971; Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993), 40 (Proteau et al., 1992) or 60 trials (Proteau, 1992). Based on these studies, it can be seen that the specificity of learning effect takes at least 70 trials to appear while the effect can be reliably shown after 150 trials of manual aiming. Although the

question has not been studied directly, research by the above authors indicates that it would not take a large amount of variability to reverse these effects. Based on the number of trials the effect takes to appear, and the positive impact that variable practice has typically had on performance, it should only take a small percentage of variable trials to negate the effect.

Practice

The concept of practice is extremely important in the field of motor learning and is a part of everyday life in the acquisition of skill. An important part of practice and its scheduling is the phenomenon known as the contextual interference (CI) effect. Battig (1966, 1979) originally studied schedules of practice, as he was interested in the idea that different aspects of a practice scenario which are initially difficult for people provide greater learning of a task once some time has passed. This effect is now known as "contextual interference" (Shea & Morgan, 1979) where practicing slightly varied versions of the same task (random practice) is not as good initially as practicing the same task repeatedly (blocked practice) but proves to be a superior method of training when it comes to retention tests.

Two explanations for contextual interference effect have been proposed. The first is the "elaboration hypothesis" where participants process the information more deeply and completely with more elaborate associations causing better long-term retention (Shea & Morgan, 1979; Shea & Zimzy, 1983). The other is the "reconstruction hypothesis" by Lee and Magill (1983; Magill, 1983) who stated that the CI effects are due to forgetting the solution to the movement

problem and having to regenerate a solution every trial. The reconstruction viewpoint attributes the retention benefits of random practice to the extensive retrieval, practice that occurs as a result of a continued interchange of task information in working memory from trial to trial (Schneider, Healy, Ericsson, & Bourne, 1995).

There has also been an effort to model the CI effect using a connectionist framework (Graf, 1995; Shea & Graf, 1994). Consistent with the reconstruction hypothesis, their simulations indicate that random practice operates at a more time-consuming/effortful processing level than those employed by blocked practice participants (Immink & Wright, 1998).

However, the various explanations discussed above are not easily testable against one another even though each of them appears plausible and has some supporting evidence (Horak, 1992). Contextual interference has been shown to improve performance on retention tests in variable practice situations. Part of this effect may be due to not only the benefits that contextual interference has on memory and re-solving movement problems but the breaking down of the negative effects of specificity. If the task is not practiced a specific way enough times, then the motor program will not have a chance to become ingrained in memory or strong enough to elicit the specificity effect and decrease performance.

Dual Vision System

So what aspect of vision is responsible for this specificity effect? The notion of a dual vision system may help us understand what is going on with vision during the performance of manual aiming movements.

Paillard (1980; Paillard & Amblard, 1985) suggested that there are two different visual channels: one kinetic and one static. The static channel would be best suited for the processing of slow visual information taking place in central vision, which is usually the case when the hand approaches the target in a conventional aiming task. On the other hand, the kinetic channel would be best suited for processing the high-speed visual information that might be available in the periphery of the retina. Assuming that participants normally look at the target they aim at, this kinetic channel appears to prefer the information that is visually available in the first half of an aiming movement. Support for Paillard's proposition was found consistently in a series of experiments conducted by Bard and colleagues (Bard et al., 1985; Bard et al., 1990; Blouin et al., 1992; Blouin et al., 1993).

Paillard and Amblard (1985) argued that a distinction has to be made between two independent visual channels as each processes different types of visual information. Both channels would operate in a closed-loop fashion and would provide either positional or directional error signals regarding an ongoing aiming movement. The first system would operate in foveal vision and account for the terminal correction of the trajectory during the homing in phase of the aiming movement. The other channel would operate faster than the former and provide information regarding the directional error of the moving limb toward the target. Furthermore, this second channel would appear to be particularly effective in the first, usually faster, part of the movement. In light of much of the research on specificity of learning, it may be suggested that the information that is

processed in central vision, is used to control movement even after extended practice. This information is used to strengthen a sensorimotor store that is relied upon during the execution of the movement (Proteau, 1992).

Results from Proteau et al. (1987), and Proteau et al. (1992) showed that the different sources of afferent information are compared to an integrated or "intermodal" representation of the expected sensory consequences. They proposed that the integrated store gives more information than simply adding different sources of afference and leads to better performance in instances where greater amounts of practice are involved. This view leads us to the conclusion that the underlying principle for skilled movement acquisition is inter-sensorimotor integration, where the available sources of sensory feedback are integrated and used in conjunction with central planning and execution processes to form the basis of movement representation.

Purpose and Hypotheses

The current project involves two experiments aimed at firstly, discovering the limits of the specificity of learning effect with respect to variability, and second, to find out what aspect of vision is responsible for the effect.

Experiment 1 will require 200 trials on a manual aiming task with six separate groups having increasingly more variability to determine how much variability is necessary to increase accuracy to the level of the control group. In essence, we are finding out how many vision trials out of 200 are needed when practicing without vision to have equally accurate performance. Experiment 2 will have four groups: two undergoing 40 trials each (moderate practice) and two

undergoing 200 trials each (extensive practice). One group from each of these practice levels will complete the task with kinetic and static vision (kinetic + static) while the other will have static vision only. Results from this experiment will help us determine whether kinetic visual information is at least partially responsible for the specificity of learning effect with respect to vision in manual aiming tasks.

The first experiment is expected to reveal that only a relatively small amount of variability (i.e., 25%) is necessary to compensate for poor performance caused by the specificity of learning effect. Based on past research, the number of task trials it should take to negate the specificity effect is approximately 25% meaning that 50 out of the 200 trials that each participant will undergo will be the same as the transfer task. This is because the specificity effect has been reliably shown at 150 trials, which would be the same amount they would get with 25% of their trials being the same as the transfer task. Although the specificity effect has been shown to appear after 70 trials of manual aiming, it is our belief that the total number of trials along with the fact that they will have 50 trials of the transfer task will combine to negate the specificity effect.

The second experiment is expected to reveal that the kinetic visual information in a manual aiming task is the cause of the specificity of learning effect with respect to vision. This hypothesis is based on previous research that has found kinetic visual information to be more important for accuracy in manual aiming tasks when compared to static vision depending on the temporal constraints (Proteau, 1995).

This is the first study to directly measure the limits of the specificity of learning effect with regards to variability as well as the first study to examine kinetic vision's role as a determinant of the specificity of learning effect. The results are important for coaches, trainers, and teachers or anyone involved with the scheduling of practice for motor skill acquisition, as they will be able to better design practice with respect to variability and specific visual information to optimize performance. This information will also be useful to motor control theorists, as they will become better able to model the specificity of learning effect and predict its effects on performance in various situations.

CHAPTER 2
REVIEW OF LITERATURE

Afferent Information in Manual Aiming

Models of Afferent Information

Dating back to Woodworth's (1899) seminal work over 100 years ago on the accuracy of voluntary movements, researchers have studied the role of different informational sources in the learning of manual aiming movements. While many early studies were concerned with the relative importance of vision and kinesthesis and/or the time it takes to use visual information, recent theoretical and technical developments have stimulated scientists to ask questions about "how" different sources of visual information contribute to motor control in different contexts. Research on how afferent information affects movement is important if we are to understand the changes in movements that occur during learning and how we control those movements. For example, which types of afferent information are more important for learning or at what stages of learning is this information critical? How does the specificity of the afferent conditions affect performance and can variability of practice alter these effects? To answer these questions it is important to look at models to give us a clearer understanding of how learning under varying afferent conditions occurs.

Several theories have been proposed to help us understand how reaching and touching or grasping is controlled. Among these, Adams (1971), in his

closed-loop theory of motor learning, stated that afferent information plays a primary role in learning and control of movement. Keele (1968), in a visual feedback control model, proposed that the distance between the hand and target is monitored visually and that this error information is used to produce corrective adjustments suggesting that afference is important only in learning and not in on-line control. Alternatively, it was proposed that the importance of afference might decrease with practice of the desired task (Schmidt, 1975). Schmidt proposed that practice enables the performer to develop motor programs that can be run efficiently without afferent input. Earlier evidence of the decreased need for afference was originally presented by Lashley (1917), who reported that an adult patient with a gunshot wound to the spine (rendering his legs deafferented) could still move both his legs. However, there is a strong possibility that not all afferent pathways were severed and that there was enough activity from the remaining fibers to convey information for movement control. The same may be said about studies with deafferented animals (McCloskey & Prochazka, 1994).

Additional studies using deafferented patients have shown that vision of the limb itself may improve the planning of subsequent movements made without vision (Ghez, Gordon, & Ghilardi, 1995). Vision of the limb may alter systemic trajectory errors in movements as calibrated feedforward commands guide the hand to a target in their view of motor control. Their findings indicated that proprioceptive input plays a critical role in motor planning by updating an internal model of biomechanical characteristics of the limb (Ghez, Gordon, Ghilardi, & Sainburg, 1995).

Others have proposed a hybrid type of control, where the control of movement is due to a combination of afferent information and central processing. In this model of control, afferent information plays an important part in both learning a task and motor control even after training (Abbs, Gracco, & Cole, 1984; Prablanc, Echallier, Jeannerod, & Komilis, 1979; Prablanc, Echallier, Komilis, & Jeannerod, 1979; Van der Meulen, Gooskens, Denier Van der Gon, Geilen, & Wilhelm, 1990). In these models, the role played by afferent sources of information is considered to be as important for the learning of the task as for its regulation after modest or extensive practice. For example, Prablanc et al. (1979a, 1979b) had their participants perform 480 finger-pointing movements in a choice reaction and movement time context. They showed that being permitted to see the surrounding environment and ongoing limb as it progressed towards the target provided better accuracy than when this afferent information was not available. Proteau et al. (1987) also showed that even after extended practice, vision of the ongoing limb still provides greater accuracy than when only vision of the target was permitted.

Closed to Open-Loop Control

Progression from a closed-loop to open-loop process of motor control and the idea that practice and learning lead to a decreased need for sensory information in a specific task originated in the 1960's (Pew, 1966). In a tracking task using a cathode ray tube, participants were asked to align a dot with a target with successive key presses by the index fingers. The activation of the left key caused the displacement of the dot to the left, whereas the activation of the right

key caused the displacement of the dot to the right. Early in practice, there was a clear indication that participants were producing discrete responses as they were waiting for the result of making one key press before making another. This was represented by a mean interresponse delay of 458 ms for the first 3 hours of practice. After 12 hours of additional practice, the interresponse time was decreased to 292 ms. Pew (1966) concluded that participants were evaluating motion in between key presses (shown by large interresponse times) in the early stages but, as expertise was gained, interresponse time was decreased significantly.

The large reduction in interresponse times has been interpreted as an indication that practice resulted in the participants' moving from a closed-loop mode of control toward open-looped control. This result led Pew (1966) to conclude that "the underlying theme of these proposals is the hierarchical nature of the control of skilled acts which develop with practice beginning with strict closed-loop control and reaching levels of highly automated action with occasional 'executive' monitoring" (p. 771). However, the results of a control condition in which participants were asked to tap alternately on the two response keys revealed a mean interresponse time of 125 ms. Given the reasonable assumptions that open-loop control had been used in the control condition, participants in the experimental condition would have had an additional 167 ms between each successive keystroke to process afferent information at the end of the practice phase of the experiment. This interval would be sufficient for the processing of visual afferent information (Carlton, 1992). Pew (1974) argued that

he did not believe that participants were not operating in a completely open-loop fashion and that movement control in general did not evolve into an entirely open-loop process.

Additional evidence of the evolution from a closed- to open-loop control comes from Schmidt & McCabe (1976) who used a barrier-knockdown, coincident timing task. The index of preprogramming (Schmidt, 1972; Schmidt & Russell, 1972) was used to determine whether there was a change in the use of afferent information for response correction over time (practice) based on response initiation and constant error in timing. This rationale for using the index of preprogramming was that if participants were not using response produced feedback to detect and correct errors, then there should be a high and positive correlation between the time at which the response was initiated and the constant error in timing. Also, if practice resulted in less use of afferent information to detect and correct errors, then the value of the index of preprogramming should increase as a function of practice. They concluded that, as a performer becomes more skilled at a task, continuous visual monitoring and feedback utilization becomes less important. A reasonable criticism of this research was made by Proteau (1992), when he stated that the index of difficulty (3.9 bits; Fitts, 1954) was very low and that the task in general was too easy. This finding may have actually led to more efficient use of a closed-loop process as opposed to progressing to the open-loop mode of control proposed by Schmidt and McCabe (1976).

Other Sources of Afferent Information

Although proprioception and kinesthetic afference provide valuable information about where the limbs are and how far they have moved (Kandel & Schwartz, 1985; McCloskey, 1978), there is much support for the notion that visual information by itself or coupled with kinesthetic information is superior to kinesthetic information alone. Gibson (1969) proposed that the sensorimotor store created during learning is affected by the discovery of multimodal invariants, which are crucial for skilled movement. This idea suggests that when there is more relevant afferent information, the ability of error correction developed during learning is enhanced. It has been found that when there is no visual information, there is much uncertainty regarding where limbs are in the environment (Howarth & Beggs, 1981; Meyer, Abrams, Kornblum, Wright, & Smith, 1988). In this sense, vision may be critical for calibration of the proprioceptive system and the maintenance of that calibration (Cordo & Flanders, 1990; Flanders & Cordo, 1989; Held & Bauer, 1967; Shimojo, 1987).

Importance of Vision in Manual Aiming

Visual Processing Time

There has long been an interest in the amount of time it takes to process visual information. Woodworth (1899) was interested in how speed affected accuracy and realized that spatial accuracy was at least partially a function of visual feedback. Hypothesizing that there was a relationship between speed and accuracy led him to conclude that short duration movements would not benefit as much from visual feedback as movements made with longer durations. He used a

task where participants drew lines on a sheet of paper with a pencil while the paper rolled at a constant speed. Back and forth movements were used where participants tried to hit a fixed target or match the endpoint at their previous movement. Speed was varied using a metronome and there were vision versus no vision conditions. He concluded that movements less than 450 ms did not benefit from visual feedback (Woodworth, 1899).

Vince (1948) conducted a similar experiment supporting Woodworth's findings while lowering the time of vision that was useful for feedback to 400 ms although this conclusion was inconsistent with later work by Fitts (1954). Fitts (1954) using reciprocal movements and manipulating movement amplitude and target size observed that the time to complete a movement was linearly related to the logarithm of twice the movement distance divided by the width of the target. Fitts originally used three different tasks to support this theory and several researchers used a variety of other tasks finding it highly reliable leading to its recognition as Fitts' Law (Fitts, 1954; Fitts & Peterson, 1964).

Estimates of visual feedback processing times at 400 ms however made vision an unlikely candidate for being involved in Fitts' Law. Superiorly controlled experiments by Keele and Posner (1968) and Beggs and Howarth (1970) showed visual processing times to be closer to 200 ms, which fit well with Fitts' Law. Several other researchers have published findings of the exact amount of time for visual processing to take place (Carlton, 1981; Pauligan et al., 1990; Smith & Bowen, 1980; Zelaznik et al., 1983;) and have found visual processing times to be as low as 100 ms, supported most recently in a study by Elliott (1993)

who indicated that visual feedback could be processed in approximately 100 ms. Now that we have established the amount of time it takes to process visual information, we turn our attention to the precise times during movement that this visual information is important and utilized during manual aiming tasks. Is vision more important during movement initiation, later on for on-line error correction, or is it necessary during the entire movement?

When is Vision Most Important?

Among movement scientists, there is little argument that vision plays a major role in the control of goal directed locomotion (Corlett, 1992). Vision has consistently been shown as ranging from very important to critical in the control of movement in several tasks such as posture, locomotion, prehension, catching, aiming, target striking, and writing (Burton, Pick, & Holmes, 1990).

Further evidence of vision's importance to response accuracy was reported by Soechting and Flanders (1989a, 1989b) who suggested that movement involves a transformation of target position from an intrinsic to extrinsic frame of reference. According to this idea, the target position of the limb must be approximated linearly from the intrinsic frame of reference to the extrinsic coordinates, which is why they found greater error in participants target aiming while in the dark.

There has been a multitude of studies aimed at determining the importance of vision and many of those have compared vision conditions to no-vision conditions. The research has been consistent and shown that performance under vision conditions has been superior in tracking tasks (Abrams, Meyer, &

Kornblum, 1990), aiming tasks using the finger (Beaubaton, & Hay, 1986; Prablanc et al., 1979a, 1979b), and aiming tasks using a stylus (Elliott, & Allard, 1985; Zelaznik et al., 1983).

Another area of interest has been to find out exactly which portions of a given movement are most important as far as vision is concerned or what role vision plays in each portion of a movement (Temprado et al., 1996). It has been proposed that when the goal is to aim at a particular target, the role of afferent information is to evaluate the difference between the target to be reached and the moving limb at the end of the so-called ballistic phase of the movement. The role of afferent information is also to provide parameters for the programming of the subsequent correction (Carlton, 1979, 1981; Crossman & Goodeve, 1963, 1983; Meyer et al., 1988; Woodworth, 1899). Abrams and Pratt (1993) used a video-aiming task that required participants to move a cursor on a slide. Results showed that practice led to an increase in the duration of the first portion of the movement whereas the time spent in the corrective phase of the movement decreased as a function of practice. These results suggest that vision was important for motor control only as the cursor (or a participant's hand in a conventional aiming task) approached the target. However, the fact that the proportion of trials showing a corrective submovement was very high and did not decrease with practice which could also indicate that the participants became more proficient at processing feedback and planning corrective movements as a function of practice (Abrams & Pratt, 1993; Proteau, 1992;). These results may lead us to believe that vision was only important during the final portion of the movement.

Support for this idea came from Carlton (1981). Carlton had participants perform aiming movements toward a target. He showed that occluding the first 50% of the trajectory led to the same movement time as occurred in a full vision condition. He concluded that vision of the first half of the movement was not important for optimal aiming accuracy. Spijkers and Lochner (1994) did a similar study using vision of the last 10%, 50%, 75%, or 100% of the movement. The results indicated that the proportion of trials that were completed on the target was lower for the 50% condition than when vision was available throughout the movement. These results were interpreted as indicating that the participants were able to process the information available in the initial portion of the movement to ensure optimal accuracy. However, this conclusion should be considered cautiously because of the large target that was used which would allow frequent contact even in a no-vision condition. At any rate it appears that the importance of vision in the first half of the movement is of very limited value for movement control based on these two studies.

However, there is some support for the importance of vision early on in a movement. Conti and Beaubaton (1976) had participants perform an aiming movement under different visual conditions including full vision, no vision, and vision of the first or of the second half of the movement. For normal and slow speeded movements, seeing the first half of one's movement resulted in a lower aiming error than having no vision did. This result may indicate that, for slower movements, seeing one's hand during the first half of its trajectory might be useful for motor control. Further evidence or explanation for vision being

important in the beginning of a movement comes from Paillard (1980; Paillard & Amblard, 1985) who suggested that there may be two visual channels: one kinetic and one static. According to Paillard's proposition, the static channel would be best suited for the processing of high-speed visual information that takes place in the periphery of the retina. Given the reasonable assumption that in an aiming task participants normally look at the target they aim at, the kinetic channel appears to prefer the information that is usually available in the first half of an aiming movement.

Considerable support for that proposition has been found by Bard and colleagues (Bard, Hay, & Fleury, 1985; Bard, Paillard, Fleury, Hay, & Larue, 1990; Blouin, Bard, Teasdale, & Fleury, 1993; Blouin, Teasdale, Bard, & Fleury, 1993), who used an aiming task under different visual conditions. Typically the results indicated that there was a lower directional error when participants were able to see the lever in the first portion of the movement. In the peripheral vision condition, participants were more accurate than when no vision was permitted. However, vision of the lever in the first portion of the movement did not improve amplitude accuracy, which was optimal under the full vision and central vision conditions.

Given that there was no distinction between amplitude and directional accuracy in Abrams and Pratt's (1993) study because of the task they used, the role played in motor control by the visual information available could not be correctly identified. Temprado et al. (1996) attempted to solve this using two experimental phases: acquisition and transfer. If one source of visual information

was useful for movement control, then having it available in acquisition should have resulted in a lower spatial error than that noted in a no-vision condition. Moreover, the withdrawal of that information, in a transfer condition performed without knowledge of results (KR), should result in a larger increase in spatial error than that noted for the no-vision condition in which only KR is withdrawn in transfer. However, if that source of information is not useful for motor control, then the spatial accuracy for that condition should not differ from that of a no-vision condition in either acquisition or transfer.

The participant's task was to make target-pointing movements with a stylus in the frontal plane within a time window of 450-550 ms with the non-preferred hand. In acquisition, aiming accuracy did not differ between a no-vision condition and a condition in which the participants could see their performing arm in the first half of the movement. This result meant that withdrawing vision of the first half of the movement in a transfer test did not affect the aiming accuracy of participants who had practiced with that information. This would suggest that vision of the hand in the first half of an aiming movement does not seem to be of any value for movement control. Results also indicated that withdrawing vision of the second half of the movement in transfer caused a severe increase in directional and amplitude root mean square error (RMSE). This study also supported a specificity of learning hypothesis as participants who were given information that was taken away in transfer did poorer than those who practiced without this information.

In general, vision was very important in tasks where the accuracy requirements were stringent because full vision conditions led to more accurate responses. This effect was not prevalent in tasks where the accuracy demands were low and the influence of vision was constant whether in the beginning the task or after extensive training.

As mentioned above, the notion that there are two visual channels has helped us discover more about the aspects of vision that are important during different phases of manual aiming movements. This dual vision system will be discussed further.

Dual Visual System

Paillard and Amblard (1985) argued that a distinction has to be made between two independent visual channels as each processes different types of visual information. Both channels would operate in a closed-loop fashion and would provide either positional or directional error signals regarding an ongoing aiming movement. The first system would operate in foveal vision and account for the terminal correction of the trajectory during the homing in phase of the aiming movement. The other channel would operate faster than the former and provide information regarding the directional error of the moving limb toward the target. Furthermore, this second channel would appear to be particularly effective in the first, usually faster, part of the movement. In light of much of the research on specificity of learning, it may be suggested that the information that is processed in central vision, is used to control movement even after extended

practice. This information is used to strengthen a sensorimotor store that is relied upon during the execution of the movement (Proteau, 1992).

Results from Proteau et al. (1987), and Proteau et al. (1992) showed that the different sources of afferent information are compared to an integrated or "intermodal" representation of the expected sensory consequences. They proposed that the integrated store gives more information than simply adding different sources of afference and leads to better performance in instances where greater amounts of practice are involved. This view leads us to the conclusion that the underlying principle for skilled movement acquisition is inter-sensorimotor integration, where the available sources of sensory feedback are integrated and used in conjunction with central planning and execution processes to form the basis of movement representation.

Kinetic Vision

In numerous daily activities we must touch or grasp things that are located in our environment. To reach our goal, we can take into account numerous sources of information. This information indicates what our body position is in relation to the intended target and surrounding environment as well as the location of our hand and of the intended target in both personal and extrapersonal space. In such tasks it is widely accepted that the "kinetic" visual information available (i.e., seeing one's hand) is an important determinant of spatial accuracy. This is the case because even extensive practice in a situation in which vision of the hand is not permitted does not enable one to be as accurate as when both vision of the hand and of the target to be reached are available (Proteau & Masson, 1997). The

above proposition is also well supported by the fact that withdrawing vision of the participants hand after a long practice of a visual aiming task during which it was available causes a severe increase in the participants spatial aiming error (Proteau, 1992).

Based on the research of Prablanc and colleagues (Prablanc et al., 1979a, 1979b) and Carlton (1981) it has generally been accepted that, contrary to Stubbs' (1976) proposition, vision of the intended target coupled to kinesthetic information coming from information of the ongoing limb is not sufficient to ensure optimal aiming accuracy. Elliot (1988) showed that aiming accuracy was identical between a conventional no-vision condition and a situation in which both the ongoing stylus and the target to be reached were visually available.

Proteau and Cournoyer (1990) reasoned that the number of trials used by the researchers might have caused these discrepancies. Prablanc et al. (1979a, 1979b) used 960 trials, and Carlton (1981) used 400 total trials while Elliot (1988) used only 14 total trials. Proteau and Cournoyer (1990) replicated these studies using 15 and 150 trials. For the first 15 trials, accuracy was similar under the vision of stylus condition and the target only condition. However, as training increased, it is also clear that the participants became more efficient in using the information provided by the luminescent stylus. These results suggested that the kinetic visual information available in an aiming task became more important for movement control as practice at the task increases. Further, it appears that what is learned during acquisition is specific to the sources of information available during that phase (Proteau & Cournoyer, 1990). These results cannot however, be

taken as evidence that the static visual cues available in a normal visual context are of no use. First, as previously reported, Prablanc et al. (1979a, 1979b) clearly showed that even after 960 trials of practice, vision of the surrounding environment prior to movement initiation helps the participants to be more accurate in a finger pointing task.

Smyth and Murray (1982), were interested in determining the role played by seeing ones hand in order to catch a ball. Participants were asked to catch tennis balls with one hand under normal conditions and with an opaque screen which obstructed the view of their own arm as well as the last 150-200 ms of the ball trajectory. They concluded that the ball requires the most visual attention in catching, but accurate and effective use of the hand is increased when the hand can also be seen. Since then it has been shown that seeing ones hand is important for optimal catching accuracy, even when the period of ball occlusion is reduced to 100 ms or below (Davids, and Stratford, 1989; Diggles, Grabiner, & Garhammer, 1987; Fischman & Schneider, 1985; Smyth, 1982).

Davids, Palmer, and Savelsbergh (1989), used similar methods as above with a volleying task and found that participants performed equally well under both conditions. This result agreed with Wallace and Newell (1983) who found that the utilization of low indices of difficulty did not result in a better performance under a full vision than a no-vision condition, whereas more difficult tasks were more accurately performed under the full vision condition. These findings suggested that the tolerable margins of error could dictate whether or not the participant uses visual information regarding the performing limb.

In their pioneering work, Held and Bauer (1967) suggested that what is critical for the normal development of visuomotor coordination is the opportunity to correlate proprioceptive visual feedback and that it is the visual kinetic cues available while one is performing an aiming or aiming-like movement that are main contributors to movement accuracy. This conclusion, however, may be task specific. In line with the Wallace and Newell (1983) and Davids et al. (1989) studies, it is very likely that the margin of tolerable error interacts strongly with the importance of visual information for the control of an ongoing movement. If the accuracy requirements of the task are very easy to meet, one can imagine the so-called ballistic part of an aiming movement can, with sufficient practice, be fine-tuned to the point that online control is not required for the attainment of the goal. In such a situation the withdrawal of visual information would not affect performance.

Static Vision

In terms of static cues available in the environment prior to movement initiation, it appears that they would only be beneficial very early in learning or else would require that the individual could see both his hand and the intended target immediately prior to movement initiation (Prablanc et al., 1979a, 1979b). In the latter case, the static cues would thus play a major role for movement planning. Finally static cues available immediately after movement completion would favor movement accuracy through a feedforward process (Beaubaton & Hay, 1986; Hay & Beaubaton, 1986).

Prablanc and colleagues (Prablanc et al., 1979a, 1979b) showed that when vision of the hand is not permitted while it moves toward a target, being permitted to see the position of ones hand and of the target to be reached prior to movement initiation, enables the individual to be more accurate than when this information is not available. They suggested that once the start and end points were determined visually, the movement could be performed adequately in a closed loop manner under kinesthetic control by comparing proprioceptive afference and the visual goal.

Abahnini, Proteau, and Temprado (1997), attempted to determine if vision of ones hand as it crosses the target, which normally occurs in central vision and is supposedly under the control of a slow-processing static visual channel, could be used so that directional accuracy is optimized. Concerning the existence of a kinetic visual channel, the results of the acquisition phase of their experiments indicated a lower directional error of aiming when the participants hand was visible in the visual periphery than when only the target to be crossed was visible. This result confirmed that the peripheral retina provided information that permitted the participants to optimize directional accuracy. However, the same advantage over the target-only condition was also found when the hand was visible only in central vision. Moreover, no differences in directional accuracy occurred between the peripheral and the central visual conditions.

Methodological Considerations

As can be seen from Temprado et al. (1996), another way to test the importance of visual information in motor control situations is to use a transfer

paradigm, where participants have variable amounts of training at a task with normal vision, and then perform the task without vision. The reasoning behind using the transfer paradigm to test the role of visual afference in motor control is two-fold. First, if vision of the starting point, moving limb and end point is allowed (or not) during the learning (or acquisition) phase and the vision condition leads to superior accuracy than when the task is performed without vision, it must be assumed that vision was somehow important for controlling the movement. Basically, in this scenario, if an individual practices the task with vision of everything involved in the task and performs better than an individual who practices the task without vision, then visual afference must be deemed important to the control of the movement (Proteau, 1992).

The second rationale has to do with all participants practicing the task with full vision, and then transferring to a no-vision condition. If withdrawing the visual information available in the acquisition phase results in an increase in aiming error, then it has to be concluded that the visual information that was denied must have been important for motor control. Alternatively, if there is not an increase in aiming error after the withdrawal of that visual information, then visual afference could not have played a major role in the control of that movement. In this case, if people who practice a task with vision are asked to complete the task without vision or vice versa and suffer a decrease in performance, then the visual information that was added or denied is important in controlling the movement (Proteau, 1992).

Thus, if we test the aiming accuracy of individuals completing various tasks under different visual feedback conditions during learning and on transfer tasks, it can be determined what afferent information is important for motor control. Additionally, if the amount of practice in different afferent conditions is varied, we can determine the importance of visual information at various levels of expertise. For example, if vision of the ongoing limb in an aiming task is very important early in learning, but its importance decreases as a function of practice, then having visual afference early in practice would be important, whereas its late withdrawal should lead to a very small decrease in accuracy. Alternatively, if it was shown that its late withdrawal leads to a larger increase in error than that found after its early withdrawal, then the only viable conclusion would be that visual information was indeed used, and even more so than in early acquisition.

Researchers have used transfer paradigms for the past four decades to determine the importance of afferent sources of information in motor learning and control. The first such research looked at an oscilloscope aiming task used by Annett (1959), in which participants put pressure on a bar to move a dot on an oscilloscope from a starting point to a target. After 50 trials of practice they performed the task without being able to see the dot move to the target. When vision was withdrawn where was a large increase in error moving the dot to the target suggesting that vision was important for motor control during the acquisition phase since only 50 practice trials were used.

Smyth (1977) had participants do a similar task with four groups using 2, 5, 50, or 400 acquisition trials with full vision and a control group doing 50 trials

without vision. The results in the no-vision transfer task indicated that the groups with only 2 or 5 trials had almost double the error of the 50 and 400 trial groups and more interestingly, the control group had almost half the error of the 50 and 400 trial groups. According to these results, visual information is important for movement accuracy although its importance appears to decrease as a function of practice. These results were replicated using a variety of movement-to-display gains (Smyth, 1978). However, this interpretation must take into account that there was virtually no difference between the 50 and 400 trial groups suggesting visual afference plays a role in control regardless of practice. Also of note is the extremely low number of trials in the low trial groups (2 and 5 trials), which may or may not have contributed to learning the task in the first place.

Another task used with the transfer paradigm is the linear position task first tested by Adams et al. (1972). They had participants learn the task for 15 or 150 trials under augmented or minimal afference conditions. The augmented condition consisted of vision, hearing the linear slide move on the rod, and spring tension for kinesthetic feedback. Participants in the minimal afference condition had a blindfold, white noise to mask the slide sound, and an almost frictionless slide to minimize kinesthetic afference. When the augmented groups were switched to the minimal afference transfer task it turned out that there was a large increase in error for the 15 trial acquisition group and an even larger one for the 150 trial acquisition group. It is apparent from these results that the afferent information in the augmented condition became more important for motor control as a function of practice.

These results were replicated by Adams and Goetz (1973), Adams, Gopher, and Lintern (1977); and by Johnson (1980), who tried to differentiate visual afference and proprioception by withdrawing them separately in the transfer task and using white noise to mask the auditory feedback. Again, the results of the above studies indicated that there was an increased amount of error as a function of practice when vision was withdrawn. The evidence also suggests that what is learned during training is specific to the conditions that skill acquisition occurs in.

The Specificity of Learning Hypothesis

Research on the Specificity Effect

More recently, in manual aiming tasks, researchers have tried to study this specificity effect by using greater numbers of acquisition trials and various types of movements. Proteau et al. (1987), used a long multi-degree of freedom aiming movement to be completed in 550 ms. The temporal constraint was to avoid the confound of any speed-accuracy trade-off. The number of trials of practice with KR was either 200 or 2000 and for each number of practice trials there was a full-vision and vision-of-target-only condition. The transfer task was the target only condition without the benefit of KR. The results showed that there was a large increase in aiming error for both groups that practiced under vision conditions and a significantly greater increase in error by the 2000 trial group when compared to the 200 trial group. The error by the 2000 trial full vision group was even larger than that of the 2000 trial target only group. These findings supported Adams

(1971) and Adams et al. (1977) and the idea that visual information becomes even more important in motor control after extensive practice.

An experiment reported by Proteau (1992) supported this conclusion using the same task with four practice levels (60, 160, 1000, and 2000) in the full vision condition and three (60, 160, 1000) in the target only condition. All conditions had to have a movement time in between 500 and 600 ms. Transfer tests were given after 60, 120, 1000, and 2000 trials for the full vision condition and after 60, 160, and 1000 for the target only group. The more trials that were performed in acquisition, the more accurate they became, however, the results were quite different for the transfer task. An important aspect of this experiment was that KR was given after each acquisition and not in transfer. The results showed that the absence of KR was not responsible for the decreased performance of the vision group, as the target-only group did not suffer from a decrease in performance. The findings indicated that participants aiming accuracy in the full vision group became greater as a function of practice while the target only group did not have any accuracy decreases. These studies led Proteau (1992) to conclude that the visual information during acquisition became more important as a function of practice.

In a manual aiming task, Elliott and Jaeger (1988) had three groups of participants complete a 35 cm movement within a MT bandwidth ranging from 300-400 ms. The first group performed the task with full vision, the second with vision of the target-only, and the third group performed the task with the lights turned off 2 s prior to movement initiation effectively making it a no-vision

condition. Participants who trained in the target only and no-vision conditions had increased error when transferred to the vision condition and participants who trained in the vision condition suffered an increase in error when performing in the other two conditions. These results replicated those in Proteau et al. (1987) quite well because, as predicted by the specificity of learning hypothesis, the addition of visual information regarding the ongoing movement caused a significant increase of error for participants who had practiced without it and vice versa.

Support for the specificity of learning hypothesis was provided by Proteau and Cournoyer (1990), when they had participants make target-pointing movements from a starting position with a stylus. Three experimental phases were used: practice, acquisition, and transfer. The practice phase was 10 trials; the acquisition phase was either 15 or 150 trials; and the transfer experimental phase was 15 trials. Participants were instructed to produce an aiming response to a target within a MT ranging from 400 to 500 ms. This design had three visual feedback conditions (full vision, vision of stylus, no vision) crossed with two practice conditions (15 or 150 trials). Again the results supported a specificity of learning hypothesis. An excellent demonstration of the specificity effect (taken from this experiment) is shown in Figure 1.

Proteau and Cournoyer (1990) concluded that learning generated a sensorimotor representation, consisting of an integration of all relevant information of a movement task, which became more tightly integrated with experience at the task.

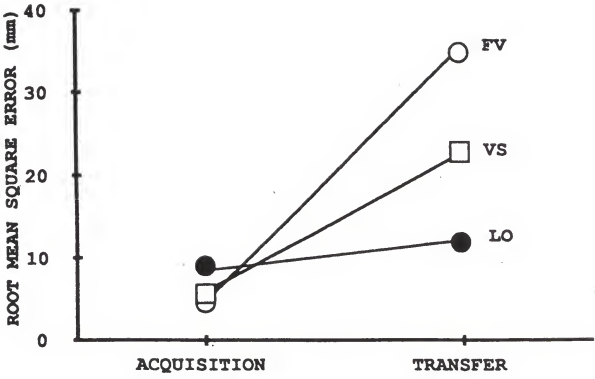

Figure 1. Root mean square error of aiming on the main axis of movement. The filled circles indicate the no-vision conditions while the open squares and open circles indicate vision of the stylus and normal vision respectively Proteau & Cournoyer (1990) (p. 821).

Explanation for the Specificity Effect

Proteau and colleagues (Proteau & Cournoyer, 1990) have proposed that the different sources of information that are used to help control a movement early in learning are compared "intramodally" (i.e., visual afference to visual expected sensory consequences) to an internal representation of the movement. This proposal is in agreement with Schmidt's (1975, 1988) idea that once a movement goal has been identified, the appropriate motor commands are issued in addition to the expected sensory consequences of the end result of the motor

commands. The actual sensory consequences would then be compared intramodally to the expected results and appropriate corrections can be made to any errors detected, time permitting. Schmidt's (1975; 1988) findings were supported by Adams et al. (1977), and Elliott and Jaeger (1988) who showed a slight increase in spatial error when vision was withdrawn early in practice. However, as learning increases, the sources of afference appear to be used in a much different manner. Results from Proteau et al. (1987), and Proteau et al. (1992) showed that the different sources of afferent information are compared to an integrated or "intermodal" representation of the expected sensory consequences.

Proteau and colleagues proposed that the integrated store gives more information than simply adding different sources of afference and leads to better performance in instances where greater amounts of practice are involved. Consequently, when one source of information used to develop this intermodal store is withdrawn, it leaves an incomplete reference and performance therefore deteriorates. This view leads us to the conclusion that the underlying principle for skilled movement acquisition is inter-sensorimotor integration, where the available sources of sensory feedback are integrated and used in conjunction with central planning and execution processes to form the basis of movement representation. Any change to the sensory conditions undermines the comparison of response-produced feedback with the multi-modal representation. Thus, rather than reducing the need for feedback, the representations of movement patterns

that develop with practice may require a particular type of feedback for the necessary comparison and corrective process to occur.

Proteau et al. (1992) designed an experiment specifically to test the specificity of learning hypothesis. They hoped to demonstrate that, for a movement-aiming task that had been learned in absence of an important source of sensory information (vision), the addition of this specific information would cause a performance decrement when compared to a control condition. The control condition in this experiment was a 40 trial pretest of an aiming task where normal vision of the task was allowed. The experimental group performed 200 trials followed by a transfer test and then an additional 1000 trials (for a total of 1200 trials) also followed by a transfer test. The experimental group practiced that task with vision of the target only for all trials. There were also two control groups, the first of which practiced for 1200 trials in the target only condition. They performed the same pre-test and transfer test as the experimental group so the only difference was the withdrawal of KR. The other control group only participated in the pre-test and transfer test without the benefit of the practice trials.

They predicted that performance in the transfer test (full vision) would be worse than their pre-test (also in full vision) because of all of the specific practice in the target-only condition. There would be no change in the control groups and the magnitude of the decrease in performance would change with the amount of practice for the participants who practiced more. Increased error on the second transfer test would support this. The second control group performed equally well

on all tests as expected. Also as expected, the first control group, who practiced the task in normal vision, improved as practice increased (i.e., second transfer test was better than first). The strongest support for the specificity of learning hypothesis came from the experimental group who actually increased in error on the transfer task with vision when compared to their performance during practice without vision. "Hence, withdrawing or adding a significant source of afferent information after a period of practice where it was respectively present or absent results in a deterioration of performance" (Proteau, 1992. p. 94). Although there was no decrease in error from the first transfer test to the second, it may be that a ceiling effect of stimulus discrimination was reached at 200 trials. Clearly there remains a need to study the limit of the effects of afferent specificity on performance (Proteau et al., 1992).

Specificity of Learning in Other Tasks

Manual aiming tasks are not the only paradigm in which the specificity of learning effect has been found. Several more applied tasks have exhibited this effect, demonstrating some generalizability to real world tasks. Robertson, Collins, Elliott, and Starkes (1994) had expert and novice gymnasts traverse a balance beam as quickly as possible with vision and no-vision (liquid crystal visual occlusion spectacles). Expert's movement times did not differ with vision condition while novices required more time to cross the beam without vision. Bennet and Davids (1995) using a powerlifting task did not find a specificity effect and neither did Whiting, Savelsbergh, and Pijpers (1995) in a one handed catching task.

Although these studies did not support a strong specificity of learning hypothesis, several reasons for this were forwarded (Proteau, Tremblay, & DeJaeger, 1998). First, Proteau et al. (1998) suggested that the novice-expert paradigm is not optimal. In the ball-catching task, expertise might result from better trajectory evaluation and timing skills. Withdrawing vision of the hand in transfer does not affect any of those skills, which might explain the rather small effect of withdrawing vision of the hand in that task. The same type of phenomenon also applies for beam walking and power lifting. In both cases, experts might perform better than novices in the no-vision transfer test at least partially because of better postural control and strength factors. Second, the transfer condition may not be sufficient to allow evaluation of the specificity of learning hypothesis. In addition it is important that the transfer condition not provide knowledge of results (KR). That requirement is important because learning is defined as a relatively permanent change that is independent of KR (Salmoni, Schmidt, Walter, 1984). Almost any form of KR could be used to modify their movement or to plan their next movement based on KR from the last trial. In the beam experiment, participants could still evaluate their performance by sensing the placement of their feet on the beam. The same type of information was available for ball catching because even if the hand was slightly misplaced, there was a strong possibility that the ball would hit the hand or arm giving them KR.

Third, the specificity of learning hypothesis is restricted to tasks requiring a high level of spatial accuracy, which was not present in the ball catching study

as points were awarded for merely touching the ball. Finally, it is very important that participants not already have extensive practice in the transfer task (no-vision). For example, gymnasts frequently walk the beam with their eyes closed during practice and Bennett and Davids (1995) reported that expert lifters did not rely on any form of visually aided training and it is generally known that lifters often close their eyes while straining to lift. In both cases, the experts clearly had more practice experience in a no-vision condition than the novices, which could explain their better performance in the no-vision transfer task.

In support of the specificity of learning hypothesis, Robertson and Elliott (1996) also used a gymnastics beam for their movement task. Through video analysis, they found results that were consistent with manual aiming studies and stated that skill development probably involves learning to use the afferent sources of information available during practice rapidly and efficiently. Proteau et al. (1998) performed an investigation attempting to control for these procedural differences using a precision-walking task. Participants practiced walking 20 m on a 2.5 cm wide line pointed on the floor for 20 or 100 trials in vision or non-vision conditions. Twenty additional transfer trials without KR were given and it was found that withdrawing vision in transfer resulted in a large and significant increase in error, which supports the specificity of learning hypothesis.

Future Directions for Specificity Research

Evidence clearly indicates that the specificity of learning effect exists in manual aiming tasks with respect to vision, and research efforts focused on replicating these findings and determining which aspects of vision could be

responsible for the specificity effect are necessary (Experiment 2 of this dissertation). Before moving on to the specific source of the effect, it seems logical to first test its limits. If specificity is a function of practice in this type of research, how many trials of the transfer task can be added to the acquisition phase to negate this effect if it is indeed possible to negate at all? Research has shown that variable practice leads to better performance in a variety of tasks (Wulf & Schmidt, 1997). The critical question that is being asked is how much variability is needed to remedy the deleterious effects of visual specificity in manual aiming tasks?

Practice

Understanding the acquisition of skill has been the focus of formal scientific interest for nearly a century, with a considerable increase during the 1960's. A goal of physical education has been the teaching of skills which were relevant for things such as job training, accident prevention, artistic performance in music and dance, man-machine interactions in equipment and vehicle design, and relearning at lost skills after traumatic injury or stroke (Schmidt, 1986).

Length and Frequency of Practice

It has been long claimed that short training sessions (distributed practice) produce faster learning than the equivalent amount of time spent with longer sessions (massed practice). Woodworth (1938) cited many studies, which appear to support this claim across a wide range of tasks from archery to maze learning and learning the skill of typing. There seems to be two ways of distributing practice. First, the amount of practice per day is a variable that many early studies

showed to be very powerful. The second is the length of the interval between successive trials which has been found to have a much less powerful effect (Perkins, 1914). Support for this effect was found by Baddeley and Longman (1977), who took a typing task and found that one hourly session per day was better than two sessions per day of two hours each.

Conditions of Practice

Battig (1966,1979) was interested in the idea that various aspects of a practice situation which initially cause difficulty for the participants (keeping slightly different versions of the tasks separate) and which make performance in practice poor, seem to provide greater learning of the task when they are later evaluated on a retention test. This effect has come to be known as "contextual interference" and although it had been studied in verbal tasks, it had not been looked at as a factor in learning. Shea and Morgan (1979) performed a simple and classic study where they used a number of different versions of a relatively simple movement task. The participants had to begin with their hand on a home position, and then knock down three barriers in a prescribed order while trying to minimize movement time. To change the task, the barriers were moved to different positions, which altered the distance and direction of the movement. The order of practice was varied between groups and all practiced for 54 trials. Practice was "blocked" in one condition meaning that 18 trials of version A were completed followed by 18 trials each of the other two versions of the task (B and C). In the "random" condition, the same number of trials of A, B, and C were completed but

the order was randomized, with no single version being present on two consecutive trials (see Figure 2.).

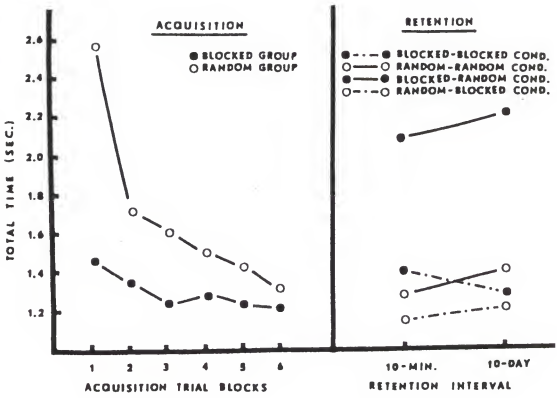

Figure 2. Mean total time measures in acquisition for blocked and random groups and retention conditions
Shea & Morgan (1979) (p. 183).

In the initial practice trials, the blocked condition produced much more effective performance than the random condition. The mixing of the different versions of the task in the random condition produced some sort of contextual interference, making the performance of each of the versions of the tasks less effective than if the learners had an opportunity to work on each of the versions

separately. The interesting finding however occurred in retention. Basically, there were two experiments where the effect of blocked or random practice in the acquisition phase was evaluated: (a) the blocked retention tests or (b) on the random retention tests, with retention tests either 10 min or 10 days after acquisition.

The group with random practice on acquisition was far faster than the group with blocked practice in acquisition. It was also found that the blocked (acquisition) – random (retention) group performs better in the acquisition phase but less effective in the retention phase. It was also found that the random-blocked condition was faster than the blocked-blocked and that random practice in acquisition was again more effective for long-term retention than blocked. Shea and Morgan (1979) concluded that participants who practiced under random conditions in the acquisition phase were more effective on the long-term retention tests. This superior performance was regardless of the conditions under which they were tested (blocked or random), but the effect was much larger for the participants tested on the random retention test.

So why does random practice make performance on retention tests better than retention tests after blocked practice? The nature of random practice and the effect that it has on performance has been studied extensively by researchers, and the cause of this improvement of performance has been attributed to a phenomenon termed "contextual interference."

Contextual Interference

Random practice is frequently used as a practice schedule to engender high CI during practice. This practice format involves practicing multiple variations of movement within a single bout of training. In contrast, blocked practice creates relatively less interference during practice as it consists of practicing the same movement repeatedly prior to the introduction of alternative movement variations that must also be learned.

Originally identified as a curious paradox in the verbal learning literature (Battig, 1966, 1972, 1979), contextual interference may be manifested (a) when there is an increase in the similarity among items to be learned or (b) when there is an increase in the variety of processing requirements on successive trials. Random practice appears to have a beneficial effect on performance due to the context in which a particular version of the task is practiced in acquisition.

Since the original demonstration of the CI effect in the motor domain (Shea & Morgan, 1979), this effect has been observed using a variety of participant populations (Del Ray, Wughalter, & Whitehurst, 1982; Edwards, Elliot, & Lee, 1986; Pollock & Lee, 1997) and environmental settings (Goode & Magill, 1988; Shea & Wright, 1991; Shewokis, 1997). Tsutsui, Lee and Hodges (1998), found that CI effects could arise in motor tasks that require the acquisition of new coordination patterns and are not limited to tasks involving novel scaling of a previously existing pattern. Few question the robustness of this phenomenon although there is much debate on the accepted explanation for the CI effect. Two theoretical positions have been put forth to explain the CI effect. The first is

elaboration hypothesis (Shea & Zimny, 1983; 1988). Central to this theoretical position is the use of two types of processing by individuals in blocked and random practice conditions. In the blocked condition, individuals rely on intratask processing. This processing type is considered to be very limited because it consists only of individual task analysis, without reference to knowledge structures. In contrast, due to the structure of random practice, it is proposed that the learner is encouraged to take advantage of both intratask and intertask processing. Intertask processing involves relational or associative processing that enables the learner to incorporate new task information with existing knowledge (Einstein & Hunt, 1980). It is the use of this intertask processing in a random practice condition that is considered to be critical in allowing the learner to formulate a detailed task representation.

Shea and Morgan (1979; Shea & Zimny, 1983) argued that the effect was due to random practice causing the participants to process information about the various versions more deeply and completely. This processing would then lead to more distinctiveness between the tasks, more elaborate associations being formed for the various versions of the task, and hence better long-term retention. Shea and Zimny (1983) using a post-practice interview found that the participants reported many more descriptions of the tasks that used extra-experimental associations and intra-experimental associations (strategies outside and inside the experimental context) for random practice. These descriptions support their views about deeper and more elaborative processing as a basis for the better retention.

A different interpretation is offered within the framework of the reconstruction hypothesis. Lee and Magill (1983; Magill, 1983) as well as Cuddy and Jacoby (1982) have argued that the contextual interference effect is caused by forgetting the solution to the movement problem. Here, the presentation of a different version (e.g., version B) of the task causes the participant to forget the "solution" to the movement problem that was just generated on a previous trial (with version A for example), which then requires the learner to generate the solution for version "A" again when it is next required. Participants under blocked conditions do not have to regenerate the solution for version "A" again when it is next required. Participants under blocked conditions do not have to regenerate the solution for the next trial, because it is the same one used on the previous trial. In this view, the generation of solutions to the movement problem is an important factor in learning, and conditions that prevent or minimize this generation process (e.g., blocked practice) will be poor for learning and long-term retention as a result.

Not only have these effects been found in laboratory tasks (Lee, 1988; Lee & Magill, 1983) but in several other experiments using real-world skills (keyboard skills, Baddeley & Longman, 1978; and serving in badminton, Goode & Magill, 1986). Goode and Magill's (1986) study investigated the generalizability of results of contextual interference effects by extending previous laboratory research to a field setting. Three badminton serves were practiced in either a blocked (low interference), serial (mixed interference), or random (high interference) practice schedule. The random group performed better on both

retention and transfer than the blocked group and the significant trial block by contextual interference interaction also supports the generalizability of contextual interference effects, as posited by Shea and Morgan (1979), to the teaching of motor skills.

The reconstruction viewpoint attributes the retention benefits of random practice to the extensive retrieval, practice that occurs as a result of a continued interchange of task information in working memory from trial to trial (Schneider et al., 1995). An increase in the amount of retrieval activity is assumed to occur because interpolated task information from working memory prior to a subsequent trial for the criterion task (Jacoby, 1978). When this situation occurs, the participant is required to reconstruct an action plan from the information that is currently available in the stimulus array. This is not the case during blocked practice, as requisite information about the criterion response can remain in working memory throughout a series of trials. Thus, the blocked practice participant experiences little if any practice in movement preparation processes.

It has been found that differences exist between high and low CI conditions with respect to the temporal demands of planning a movement (Immink & Wright, 1998). In their 1998 study, they found data consistent with the nature of temporal delays that would be predicted for random and blocked practice schedules by the reconstruction hypothesis (Carlson & Yaure, 1990; Lee & Magill, 1983; 1985; Schneider, et al., 1995).

There has also been an effort to model the CI effect using a connectionist framework (Graf, 1995; Horak, 1992; Masson, 1990; Shea & Graf, 1994).

Although each of these efforts have succeeded in modeling the basic characteristics of the CI effect, only Graf and colleagues (Graf, 1995; Shea & Graf, 1994;) have sufficiently developed a model to entertain predictions about the extent of the planning operations that are carried out during random and blocked practice formats. Consistent with the reconstruction hypothesis, their simulations indicate that random practice operates at a more time-consuming/effortful processing level than those employed by blocked practice participants (Immink & Wright, 1998).

Schema Formation

Another argument for the enhanced retention and transfer performance relative to random practice is that it may be due to the formation of motor schema (Schmidt, 1975). According to Schmidt's schema theory, variable practice within a movement class, governed by a generalized motor program with certain invariable characteristics, leads to the formation of motor schema as the relationship between movement outcome and the corresponding movement parameters (recall schema) as well as between the outcome and the sensory consequences (recognition shema). Motor schema are not only assumed to be more stable than movement information associated with constant practice, producing superior retention performance, but they are also assumed to allow for a better inter- or extrapolation of novel parameters and a better prediction of the sensory consequences, leading to superior performances (Wulf & Schmidt, 1988). Wulf and Schmidt conducted a study involving a sequential timing task where one group (schema) receive variable practice within one movement class, while

practices for another group (context) involved the same absolute movement directions, as well as a different phasing pattern for each task version. On a transfer task, the schema group performed more effectively than the context group, this supporting schema theory. However, on the transfer task with new phasing requirements, the context group demonstrated performance superior to that of the schema group.

A related study, published by Hall and Magill (1995), attempted to determine whether learning benefits in multiple-task learning situations are a result of contextual interference or of schema enhancement related to the amount of variability in the practice session. The results were consistent with Magill and Hall's (1990) predictions that the learning benefits of contextual interference were more likely to occur when skill variations are from different classes of movement and that the amount of variability in practice is more influential when the to-be-learned tasks and parameter modifications are of the same generalized motor program.

Practice Variability

Several studies have shown that practicing task variations with the same underlying movement structure but with different overall force or duration (i.e., parameter) requirements can enhance retention and transfer, compared with constant practice. These studies used tasks such as throwing objects at targets of different distances (Kerr & Booth, 1978; Wulf, 1991) moving the limb a certain distance with different speeds (McCracken & Stelmach, 1977), propelling objects to targets at different distances (Kelso & Norman, 1978), producing certain

amounts of force (Shea & Kohl, 1990, 1991) and pursuit tracking tasks (Wulf & Schmidt, 1997). In fact, Shea and Kohl (1990) provided evidence that practicing variations of a criterion task is better for retention than constant practice for the specific criterion.

Basically, the idea is that practice variability enhances the effectiveness of rules (schema) that relate the external task requirements to the internal movement commands. However, past experiments suggest that variable practice alters the practice context to force a change in behavior from trial to trial, encouraging additional information processing activities about the lawful relationships among the task variants. The result is learning that contributes to performance on the test of retention or generalizability, even though these activities detract from momentary performance during the acquisition phase (Schmidt & Bjork, 1992). Eidson and Stadulis (1991) tested Schmidt's (1975) schema theory hypothesis of variability of practice on the performance of both a closed and an open motor skill. They found that for a closed skill, constant practice groups exhibited more absolute error than the variable practice groups during performance of a transfer task while no significant effect of type of practice for the open skill was obtained.

Summary of Practice

Because practice is the key to successful and optimal performance it is important to understand the concepts and related phenomena to further our knowledge and help us design the most efficient ways to practice. Through the study of practice we have determined that practice of short duration (distributed practice) is superior to lengthier durations (massed practice) (Baddeley &

Longman, 1977). It has also been determined that random practice provides for greater learning on retention test than does blocked practice (Shea & Morgan, 1979). The contextual interference effect appears to be the cause of the superiority of random practice over blocked practice as it promotes enhanced learning through either an elaboration or reconstruction process. An alternative theory is schema theory that states that variable practice within a movement class leads to the formation of motor schema which are more stable than information associated with constant practice and allow for better comparisons and predictions of sensory consequences, leading to superior performances (Wulf & Schmidt, 1988).

Schema theory offers a good explanation of how practice variability affects performance. According to this theory, practice variability enhances the effectiveness of rules (schema) that relate the external task requirements to the internal movement commands. Variable practice forces a change in behavior from trial to trial, encouraging additional information processing activities about the lawful relationships among the task variants.

By applying the concepts of practice variability and schema theory, it is our hope that the negative effects that specificity of practice, with regards to vision, has on performance in manual aiming tasks, can be negated. By determining how much variability is necessary to achieve this goal, we can further our knowledge on efficient methods of practice to ensure optimal performance in manual aiming tasks.

CHAPTER 3
VARIABILITY: HOW DOES IT AFFECT THE SPECIFICITY OF LEARNING HYPOTHESIS?

Introduction

The Specificity of Learning Effect

The concept of practice has been researched throughout the century primarily due to its significance in learning and performance. Lately, an interest in the notion of specificity of learning has been renewed in the literature. This research has resulted in the extension of the original idea of specificity of learning, that performance on one task is not useful for predicting performance on other tasks (Henry, 1968) to the more comprehensive idea that learning and subsequent performance are specific to the conditions in which learning takes place (e.g., Proteau, Marteniuk, & Levesque, 1992). When practice is completed under a specific set of afferent information (i.e., information coming from one of the senses such as sight, sound or touch), there is a distinct specificity of learning effect (Adams, Gopher, & Lintern, 1977; Proteau, Marteniuk, Girouard, & Dugas, 1987). Adams et al. (1977) originally argued in favor of the concept of a specificity effect and proposed that visual afference becomes more important in controlling motor skill after extensive practice. Proteau et al. (1987) discovered that the addition of visual information in an ongoing movement caused a significant increase in error for participants who practiced without it and vice

versa. Proteau and Cournoyer (1990) added to the knowledge base concerning the specificity effect by proposing that practicing a task under specific afferent conditions results in a representation consisting of an integration of all relevant information of a movement task and that this representation becomes more tightly integrated with increased practice. The specificity of learning hypothesis is described clearly by Proteau (1992) who stated that withdrawing or adding a significant amount of afferent information after a period of practice, where it was respectively present or absent, results in a deterioration of performance.

In the literature, there has been much research on the specificity of learning hypothesis but relatively little on its limits or causes (Proteau, Marteniuk, & Levesque, 1992). The transfer paradigm appears to have been the most common way to study vision's role in the specificity of learning (Annett, 1959; Johnson, 1980; Smyth 1977; 1978; Temprado et al., 1996). The transfer paradigm has been used to determine that there is indeed a specificity of learning effect (Adams, Goetz, & Marshall, 1972; 1977; Proteau, 1992; Proteau & Cournoyer, 1990; Proteau et. al., 1987). An explanation of the specificity of learning effect may be that it is due to the building of a strong multi-modal representation that causes performance decrements when the representation is not matched in the task requirements (Proteau et al., 1992). For example, if vision were to be efficiently used, relevant information from this modality would be incorporated into the sensorimotor store for the task. In this case, adding vision probably resulted in the participants attending to this new information and neglecting the basis on which

the task had been learned because of its dominance as a source of information (Proteau et al., 1992).

The questions that are being asked in this research relate to the strength of the specificity of learning effect, and the ability of the specificity of learning effect to be altered or changed by a mediating factor. The purpose of this experiment is to test the limits of the specificity of learning effect with regards to variability and to discover how much variability is required to negate the deleterious effects on outcome when the task is performed with different afferent conditions.

Past research has indicated how much specificity is needed to promote the appearance of a negative effect with respect to vision (Elliot & Jaeger, 1988; Proteau, 1992; Proteau & Cournoyer, 1990; Proteau et al., 1987), but little is known about the limits of the specificity of learning effect. The number of trials taken to elicit the specificity effect has never been directly determined but the limits can be surmised by the many studies revolving around the specificity of learning effect. Elliott and Jaeger (1988) identified the specificity of learning effect after only 70 trials of a manual aiming task while the effect has been more reliably found to appear after 150 (Adams, 1972; Proteau & Cournoyer, 1990), 160 (Proteau, 1992), 165 (Proteau & Marteniuk, 1993) and 200 trials (Proteau et al., 1987; Proteau et al., 1992; Proteau & Marteniuk, 1993). Several studies support the notion that the more trials that are performed, the stronger the specificity effect will be (Proteau, 1992; Proteau & Marteniuk, 1993; Proteau et al., 1992; Proteau et al., 1987). Moreover, research has shown the number of trials

that were not enough to elicit the effect. The specificity of learning effect was not found when 15 (Adams, 1971; Proteau & Cournoyer, 1990; Proteau & Marteniuk, 1993), 40 (Proteau et al., 1992) or 60 trials were performed (Proteau, 1992). Based on these studies, we can predict that the specificity of learning effect takes at least 70 trials to appear while the effect can be reliably shown after 150 trials of manual aiming. Although the question has not been studied directly, research by the above authors leads to the conclusion that a large amount of variability would not be necessary to reverse these effects. This conclusion is based on the number of trials the effect takes to appear and the positive impact that variable practice has on performance.

Practice Theory

The concept of practice is crucial to the field of motor learning and is a common part of everyday life and in the acquisition of motor skills. An important part of practice and the scheduling of practice is the contextual interference (CI) effect. Battig (1966, 1979) originally studied schedules of practice, as he was interested in the phenomenon where different aspects of a practice situation which are difficult for people to begin with, but provide greater learning of a task once practice has occurred. This phenomenon is known as "contextual interference" (Shea & Morgan, 1979) where practicing slightly varied versions of a task (random practice) is not initially as beneficial as practicing the same task repeatedly (blocked practice) but proves to be a superior method of training when applied to retention tests.

There have been two explanations proposed for the contextual interference effect. The first explanation is the "elaboration hypothesis" where participants process the information more deeply and completely with more elaborate associations causing better long-term retention (Shea & Morgan, 1979; Shea & Zimzy, 1983). The other explanation is the "reconstruction hypothesis" proposed by Lee and Magill (1983; Magill, 1983) who stated that the CI effects are due to forgetting the solution to the movement problem and having to regenerate a solution on every trial. The reconstruction viewpoint attributes the benefits of retention from random practice to the extensive retrieval and practice that occurs as a result of a continued interchange of task information in working memory from trial to trial (Schneider, Healy, Ericsson, & Bourne, 1995).

There has also been an effort to model the CI effect by using a connectionist framework (Graf, 1995; Shea & Graf, 1994). Consistent with the reconstruction hypothesis, simulations appear to indicate that random practice operates at a more time-consuming/effortful processing level than methods employed by participants in a blocked practice framework (Immink & Wright, 1998).

However, the explanations discussed above are not easily testable against one another even though each of them appears plausible and has some supporting evidence (Horak, 1992). Contextual interference has been shown to improve performance on retention tests in variable practice situations. The contextual interference effect may be due to not only the memory benefits and the re-solving of movement problems but the breaking down of the negative effects of

specificity. If the task is not practiced a specific way enough times, then the sensorimotor representation will not have a chance to become ingrained in memory or strong enough to elicit the specificity of learning effect and the decreases in performance that accompany it.

Practicing motor skills is a the key to successful and optimal performance, thus, understanding the concepts and related phenomena will further our knowledge and help us design the most efficient ways to practice. Through the study of practice we have determined that practice of short duration (distributed practice) is superior to practice of lengthier durations (massed practice) (Baddeley & Longman, 1977). Also, random practice results in greater learning on retention test than does blocked practice (Shea & Morgan, 1979). The contextual interference effect appears to be the cause of the superiority of a random practice schedule over a blocked practice schedule as it promotes enhanced learning through either an elaboration or reconstruction process. An alternative theory to explain the benefits of random practice is schema theory which states that variable practice within a movement class leads to the formation of motor schema which are more stable than information associated with constant practice and allow for better comparisons and predictions of sensory consequences, leading to superior performances (Wulf & Schmidt, 1988).

Schema theory offers a good explanation of how practice variability affects performance. According to this theory, practice variability enhances the effectiveness of rules (schema) that relate to external task requirements to the internal movement commands. Variable practice forces a change in behavior from

trial to trial, encouraging additional information processing activities about the lawful relationships among the task variants.

The concepts of practice variability and schema theory have provided the tools to affect practice in a positive way. By applying these concepts, the deleterious effects of the specificity of learning effect (with regard to vision) can be negated with respect to manual aiming tasks. By determining how much variability is necessary to achieve this goal, we can further our knowledge on efficient methods of practice to ensure optimal performance in manual aiming tasks.

Purpose and Hypotheses

This experiment required 200 trials on a manual aiming task with two groups having increasingly more variability to determine how much variability is necessary to increase accuracy to the level of the control group. In essence, we are finding out how many vision trials out of 200 are needed when practicing without vision to have equally accurate performance. This experiment is expected to reveal that only a relatively small amount of variability (i.e., 25%) is necessary to compensate for poor performance caused by the specificity of learning effect. Based on past research, it is hypothesized that the number of task trials taken to negate the specificity effect is approximately 25% meaning that 50 out of the 200 trials that each participant will undergo will be the same as the transfer task. This is because the specificity effect has been reliably shown at 150 trials, which would the same amount they would get with 25% of their trials being the same as the transfer task. Although the specificity effect has been shown to appear after 70

trials of manual aiming, it was hypothesized that the total number of trials, along with the fact that the participants had 50 trials of the transfer task, would be able to combine to negate the specificity effect.

This was the first study to directly measure the limits of the specificity of learning effect with regards to variability. The results are important for coaches, trainers, and teachers or anyone involved with the scheduling of practice for motor skill acquisition, as they will be able to better design practice with respect to variability and specific visual information to optimize performance. This information is also useful to motor control theorists, as they will be closer to being able to model the specificity of learning effect and predict its effects on performance in various situations.

Method

Participants

The participants were 60 right-handed (Oldfield, 1971) volunteers from the University of North Dakota (mean age 20.46; 36 males and 24 females). All participants read and signed informed consent and received no compensation. None of the participants were familiar with either the experiments or the notions being tested. All participants had normal or corrected to normal vision.

Apparatus

Participants were seated facing a computer monitor (Gateway EV700 17 inch monitor powered by a Gateway E3200 computer) and a 30.48 cm x 30.48 cm graphics tablet (Summagraphics SummaSketch III). The monitor was located 1 m above the floor on a desk. The graphics tablet was placed directly in front of the

monitor, on a level surface 15 cm below the monitor, which allowed the participants to comfortably rest the forearm horizontally on the tablet surface (see Figure 3).

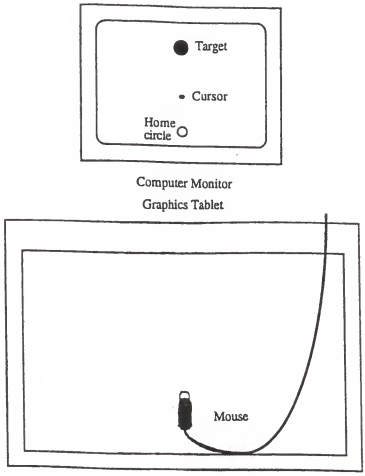

Figure 3. Monitor and graphics tablet.

The participants held a mouse (SummaSketch 4-button mouse) with the right hand and made all movements with the mouse. At the anterior end of the mouse there is a clear plastic pointer, which had a 5 cm diameter circle with two wires intersecting and forming a crosshair within the circle. The coordinates of

the crosshair intersection on the tablet surface were translated by the graphics tablet and computer as the location for the mouse. The mouse was held with the tip of the index finger placed in the crosshair (see Figure 4).

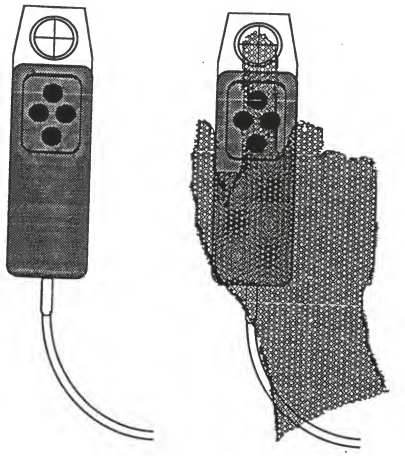

Figure 4. Tablet mouse and hand position.

The location of the finger (crosshair) was translated into the coordinates of the cursor on the monitor. The translation was performed with unity gain meaning that a 1 mm displacement of the mouse crosshair resulted in a 1 mm displacement

of the cursor on the monitor. The cursor appeared as a blue solid circle 2 mm in diameter. The output signal from the graphics tablet was sent to the computer and sampled at a rate of 121.5 Hz. Data from the graphics tablet and aiming program were accurate to .1 mm and 8 ms.

The two measures of interest were movement time and movement accuracy. Having the participants' movement times fall within a 375 ms – 425 ms bandwidth was a time constraint established because of the well-known relation between speed and accuracy (Fitts, 1954). This time restriction put conflicting demands on the participant. If the participants tried to use visual feedback to reduce error, then they would have had to reduce movement time during a trial to keep visual information available as the cursor approaches the target in spite of the general decrease in accuracy with an increase in movement speed. Movement accuracy was analyzed after computing radial error derived from error on the x and y-axis as prescribed by Hancock, Butler, and Fischman's (1994) 2-D error measurement method.

Procedure

Participants were first given an information sheet to read, which provided the information needed to complete the experiment. Verbal descriptions of the trials and how to complete them were also provided. The participants were seated facing the graphics tablet and monitor with the midline aligned approximately with the monitor. The graphics tablet was placed directly in front of the monitor, on a level surface 15 cm below the monitor. This position allowed the movements of the right limb to be made comfortably within ipsilateral space. The participants

sat close enough to the tablet so that the reaching movements did not necessitate full extension of the arm.

Each trial began with a display of the mouse-cursor and the home circle or starting position. The home circle was 4 mm in diameter, red in color, and was located centrally at the bottom of the monitor display. This starting position corresponded to a central location approximately 8 cm from the bottom edge of the tablet's active area. Once the home circle and cursor appeared on the monitor, the participant moved the cursor to the home circle and 3 s after the appearance of the home circle and cursor, a circular target (2 mm in diameter) appeared 13 cm from the center of the home circle. The index of difficulty for this experimental set-up was 3.41 bits.

A start tone accompanied the appearance of the target and signaled the trial to commence. At that point, the cursor was turned off if it was a non-vision trial, and kept on if it was a full-vision trial. Once the start signal sounded, and the participant attempted to move the mouse to the target within the required movement time of 400 +/- 25 ms. The timer stopped once the movement was complete, and the coordinates where the cursor stopped were recorded.

The task was to move the cursor from the starting point to the target as accurately as possible within the 400 +/- 25 ms bandwidth. These movements were made at the midline, directly forward and away from the participant's body with the right hand. Five practice trials were allowed before the actual testing began. The participants were instructed to keep their limb motionless at the end of the movement until the feedback display appeared. The feedback display showed

the home circle, the initial position of the cursor, the target, as well as a trace of the movement path and the final position of the cursor. A numeric display was also included which showed the reaction time, movement time, as well as the x and y coordinates with respect to the target. Thus, during acquisition, participants received knowledge of results about movement error on every trial. Participants were randomly assigned to one of six experimental groups described below. The independent variable was the vision condition (% of vision trials).

Vision Conditions

There were six total groups making up two sets of four groups for later comparison. Two of the six groups were involved in both sets. One group received 200 full vision acquisition trials while another received 200 non-vision acquisition trials. Each of these groups completed a full-vision and a non-vision transfer test (with the first transfer being similar to the acquisition condition and the second transfer test being the opposite). The transfer tests were completed after the acquisition phase and 5 minutes of off-task activity (i.e., reading). The vision transfer group had a 25% vision condition and a 12.5% vision condition that had 25% and 12.5%, respectively, of their 200 trials with vision of the cursor and the remaining trials without vision of the cursor. The non-vision transfer group had two similar conditions but with the 25% and 12.5% of their 200 trials being without vision of the cursor. The vision transfer group had a transfer test with vision of the cursor while the non-vision transfer group had a transfer test without vision of the cursor (see Table 1.). No feedback was provided during any of the transfer tests. The reason two comparison groups were used was to show

Table 1.
Experimental Condition Setup

Vision: Transfer 1		Non-Vision: Transfer 2	
Acquisition	Transfer	Acquisition	Transfer
Full Vision	Full Vision	Full Vision	Non-Vision
25% Full Vision	Full Vision	25% Non-Vision	Non-Vision
12.5% Full Vision	Full Vision	12.5% Non-Vision	Non-Vision
Non-Vision	Full Vision	Non-Vision	Non-Vision

the specificity of learning effect and the effect of variability of practice from both directions yielding a more complete analysis. There was a group that went from non-vision to vision transfer as well as a group that went from vision to a non-vision transfer. This format was used to show that specificity of visual condition was the driving force behind any group differences and not the addition or subtraction of the visual condition itself.

Analyses

There were four main objectives to the analyses. First, the movement times were checked to confirm that the movements were all performed within the prescribed movement time range (400 ms +/- 25 ms) to control for any speed-accuracy trade-off. Second, the amount of error in each block of 20 trials was checked to confirm that there was a learning effect. Third, the mean error in last block of acquisition trials was compared to that of the transfer test to determine if the specificity of learning effect was present. Last, an analysis on the error in the transfer groups was performed to evaluate any differences between the conditions

in the transfer test to see if variability of practice negated the specificity of learning effect for either of the experimental conditions. The statistics used for each objective are described in the results section and a 0.05 alpha level was used throughout to determine statistical significance.

Results

Speed-Accuracy Trade off

Movement times were analyzed to confirm that all movements were performed within the prescribed movement times (.375 to .425 ms.). Because differences in transfer groups (i.e., vision and non-vision) and specific group differences (i.e., varying the percentages of trials with/without vision) were not relevant, the data were collapsed across all groups and conditions. The number of participants in each of the 10 acquisition blocks was 60. Table 2 contains the means, standard deviations, and ranges for all of the acquisition blocks.

Table 2.
Mean Movement Time in Acquisition Blocks

Block #	Mean MT	SD	Min	Max
1	.420	.029	.359	.505
2	.413	.027	.344	.470
3	.410	.028	.331	.492
4	.409	.028	.340	.476
5	.405	.035	.321	.488
6	*.405	.030	.339	.499
7	*.401	.031	.316	.506
8	*.403	.030	.309	.490
9	.406	.031	.323	.495
10	*.404	.021	.355	.455

* denotes significant decrease in movement time from Block #1.

Examination of Table 2 shows that all of the means were within the prescribed range. A repeated measures ANOVA indicated that there were significant differences across the acquisition trials, $F(9,711) = 6.02$, $p < .01$. This result confirms that the participants adhered to the temporal constraints of the task, which effectively controlled for the speed-accuracy trade-off. A Tukey's HSD post-hoc test revealed that movement times generally decreased over trials. Significant differences were found between block 1 and 6, 1 and 7, 1 and 8, and 1, and 10. These results indicate that as participants became more familiar with the task, movement times in general became closer to the 400 ms goal time.

Learning Effect

Similar to the speed-accuracy trade-off analysis, this analysis was used to confirm that there was a learning effect. The data were collapsed across transfer groups and conditions (i.e., $N = 60$ for each block). Means, standard deviations and ranges for error scores are also included in Table 3.

Table 3.
Mean Error in Acquisition Blocks

Block #	Mean Error	SD	Min	Max
1	14.17	4.41	7.42	25.68
2	* 11.42	3.00	5.68	20.09
3	* 11.01	3.09	6.00	23.42
4	+* 9.86	2.44	5.47	15.57
5	* 10.01	2.99	5.07	18.56
6	#+* 9.92	3.54	4.08	25.46
7	#+* 9.24	3.00	4.38	16.60
8	#+* 9.11	2.54	3.28	15.93
9	#+* 9.05	2.95	3.95	15.64
10	#+* 8.76	2.40	4.10	15.24

*denotes a significant difference from Block 1.
+denotes a significant difference from Block 2.
#denotes a significant difference from Block 3.

The repeated measures ANOVA on the error scores revealed significant differences across the acquisition trials, F (9,711) = 59.97, $p < .01$. Tukey's post hoc analysis showed that the participants' error scores decreased over time demonstrating the learning effect. Significant differences were found between block 1 and all other blocks (2 – 10), between block 2 and blocks 4, 7, 8, 9, and 10, and between block 3 and blocks 7, 8, 9, and 10. In all cases, the early blocks had higher errors scores compared to the later blocks. These results set the stage for the specificity of learning effect to appear.

Specificity of Learning Effect

To determine if the specificity of learning effect was present, a 4 (Condition) X 2 (Phase) mixed design two-way ANOVA with repeated measures on the second factor was used to determine the effects of adding or withdrawing visual information on aiming accuracy during transfer. Where appropriate, Tukey's follow-up procedure was used. Analyses were conducted separately for the vision and non-vision transfer groups; for both analyses, the dependent variable was spatial error.

The results of the non-vision transfer analysis are shown in Figure 5. For the non-vision transfer group, the main effect for condition was significant, F (3,36) = 2.99, $p < .05$. There was also a significant main effect for phase, F (1,36) = 27.88, $p < .01$. Superseding the main effect was a significant condition by phase interaction, F (3,36) = 9.60, $p < .01$ indicating that performance did not increase or decrease at the same rate for the groups. Error scores for the full vision and 12.5% non-vision groups significantly increased, whereas there was essentially no

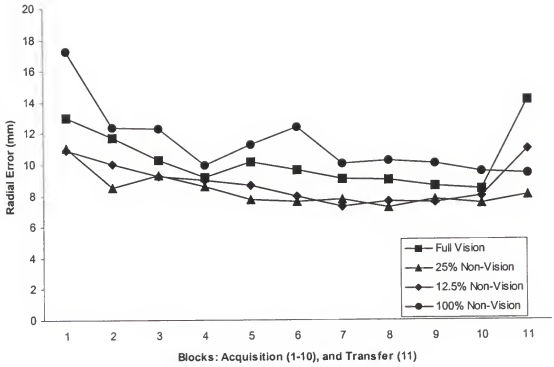

Figure 5. Radial error by block in the non-vision transfer.

change in error scores for the 25% non-vision and no-vision groups. There were no group differences for the acquisition block. However, for the retention phase, the full vision group performed worse than the other three groups ($p < .01$). In terms of mean differences, even though the 12.5% non-vision group also performed with slightly greater error on the retention trials, only the results for the full vision group were statistically significant.

For the vision transfer group, the main effect for condition was significant, $F(3,36) = 5.77$, $p < .01$. There was not a significant main effect for time ($p > .05$). However, there was a significant condition by time interaction, $F(3,36) = 3.55$, $p < .05$. The results are graphed in Figure 6.

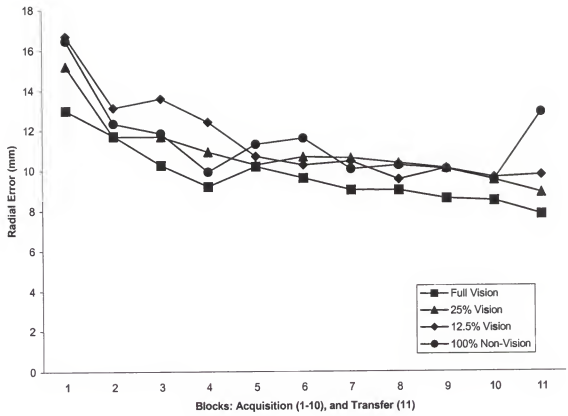

Figure 6. Radial error by block in the vision transfer.

With respect to time, the only significant difference was that the error scores for the non-vision group significantly increased from the acquisition to the retention trials ($p < .05$). Similar to the previous analysis, there were no group differences for the acquisition phase. However, for the transfer phase, the non-vision group performed worse than all other three groups ($p < .01$).

Variability Effects

The final analysis was designed to test for differences between the transfer groups to reveal any effects of having 25 or 50 of the trials matching the transfer condition, which equated to 12.5% or 25% variability. A 4 (Condition) X 2

(Phase) mixed design two-way ANOVA with repeated measures on the second factor showed that there was a significant main effect in the vision transfer, $F(3,36) = 9.91$, $p < .01$, and in the non-vision transfer, $F(3,36) = 5.10$, $p < .01$. In the vision comparison, the post hoc test showed that the non-vision group was significantly different from the other 3 groups. This result for the vision transfer indicates that when visual information was added to the transfer condition, participants in the non-vision condition suffered a decrease in accuracy whereas the other three groups (full-vision, 25% vision, and 12.5% vision) were unaffected. In the non-vision comparison, the post hoc test revealed two significant differences ($p < .05$). The analysis indicated that the full-vision group performed with less accuracy than both the 25% non-vision group and the non-vision group. In this case, withholding visual information led to the full-vision group to perform the aiming task with greater error than the non-vision, and 25% non-vision groups but not the 12.5% non-vision group.

Discussion

This study was designed to replicate the specificity of learning hypothesis (Proteau & Cournoyer, 1990; Proteau et al., 1987; and Proteau et al., 1992) which suggests that visual information used to learn and control an aiming movement does not decrease in importance with practice but, rather, increases in importance (Adams, et al., 1977; Elliot & Jaeger, 1988; Proteau, 1992; and Proteau et al., 1992). There has been little research aimed at the limits or causes of the specificity of learning effect (Proteau, et. al., 1992) and to effectively test the limits of the specificity of learning hypothesis, certain requirements had to be

fulfilled. The first was that the speed-accuracy trade-off (Fitts, 1954) had to be controlled. If the participants performed the task outside of the 375-425 ms movement time bandwidth, it would be easier to perform with greater accuracy (if moving slower) and therefore compromise the error results. This requirement was met as the mean movement times for each block all fell within the 375-425 ms bandwidth. As acquisition continued the participants came even closer to the goal movement time of 400 ms also supporting somewhat of a learning effect. The second requirement was that a learning effect over acquisition had to be found. For the learning effect to be realized, participants had to show a significant improvement in performance over time with learning being a relatively permanent change in performance independent of KR (Salmoni, Schmidt, and Walter, 1984).

The results of this study indicated that there was indeed a learning effect as participants' error decreased over the acquisition period and the fact that participants' movement times came closer to the goal of 400 ms over acquisition as well. The learning effect (significant improvement due to practice) naturally precedes the specificity of learning effect and since the effect was confirmed, further analyses were conducted. The third requirement concerned finding the specificity of learning effect. The decision to look at the specificity effect from both directions was to obtain a more reliable indication of variability's effect on the specificity of learning effect. In the non-vision transfer (looking at the effects of withdrawing visual information in the transfer condition) the groups that practiced with 100% and 87.5% of the trials with vision of the cursor suffered decreases in accuracy when performing in the non-vision transfer. However, the

groups that practiced with only 75% and 0% of their trials including vision of the cursor did not have any increase in error. This result clearly shows that the specificity of learning effect was present when learning with vision in acquisition and then performing the same task in transfer without vision.

As for the specificity of learning effect in the other direction (looking at the effects of adding visual information in the transfer condition), the analysis indicated that the group that practiced with 100% of the trials without vision suffered decreases in accuracy. However, the groups with only 87.5%, 75%, and 0% of their trials without vision did not have these increases in error. Again, the specificity of learning effect was found, showing the effect to be replicated in both directions. An original hypothesis was that the specificity of learning effect would be present and the current findings confirmed this general trend in the literature (Proteau, 1992; Proteau & Marteniuk, 1993; Proteau et. al., 1987, 1992).

As all the requirements were met, the effects of variability of practice could be determined with respect to the specificity of learning effect. The specificity of learning effect identified in the present experiment as well as in several others reported in the literature recently (Abahnini et al., 1997; Proteau & Cournoyer, 1990; Proteau et al., 1992; Temprado et al., 1996) is responsible for decrements in performance although the limits were not investigated until the present study. A primary hypothesis involved the variability of practice in sufficient amounts and consequently to eliminate the specificity of learning effect. To negate the specificity of learning effect, the participants who practiced the skill with varying amounts of variability had to maintain their level of performance

when faced with a transfer condition opposite from acquisition. Differences in both directions of the specificity of learning effect were found showing that variability of practice can remedy the decreases in performance. In the vision acquisition to a non-vision transfer, there were distinct differences between the group that practiced with vision of the cursor in 100% of the trials and the ones with 0% and 75% vision trials, respectively. In this case, all participants performed 200 acquisition trials and then completed a non-vision transfer. As would be expected, the group that learned the task with vision performed far worse than the group that learned the task without vision when going to the non-vision transfer. These results show that dispersing 50 trials without vision out of 200 during acquisition acted to negate the poor performance found in the group without variability of practice. This was not the case with the group that were given 25 trials without vision during acquisition. This result shows that only 25% variability was necessary to overcome the specificity of learning effect whereas 12.5% variability was not.

In the non-vision acquisition to vision transfer, slightly different results were found. In this case, the non-vision group suffered significantly greater error than all three of the other groups. However, dispersing 50 trails of the transfer condition (vision) served to eliminate the decrement in performance found in the non-vision group. In fact, only 25 trails of vision were required to negate the specificity of learning effect found in the non-vision group. Adding 25% variability was again enough to compensate for the specificity of learning effect. This time however, even the addition of 12.5% variability was enough to

overcome the poor performance caused by the specificity of learning effect. These results showed that variability of practice can be a considerable benefit to performance, which has long been emphasized in the literature, yet not applied to the specificity of learning effect until this study (Kelso & Norman, 1978; Kerr & Booth, 1978; McCracken & Stelmach, 1977; Shea & Kohl, 1990, 1991; Wulf and Schmidt, 1997). Although variability may detract from performance momentarily during the acquisition phase, these activities contribute to performance on tests of retention and transfer (Eidson & Stadalis, 1991; Schmidt & Bjork, 1992).

The results of this study have given some fairly clear indicators that variability of practice can have a strong influence over the specificity of learning effect. When 25% of the practice trials are executed with the same visual information as the performance task, there is adequate variability in acquisition to overcome the deleterious outcome of the specificity of learning effect. Morover, as little as 12.5% variability was sufficient to overcome decreased accuracy as a result of the specificity of learning effect in the non-vision transfer reported in this experiment. The results of this study supported all of the hypotheses with the most important one being that variability of practice is able to effectively negate the specificity of learning effect. These findings contribute to the literature by further defining the limits of the specificity of learning effect. Thus, researchers now know that the specificity of learning effect will disappear after 25% or even as little as 12.5% variability in a manual-aiming task.

These results also have positive implications in designing more efficient practice for learning a skill. For example, when coaches want to effectively teach

motor skills, they must ensure that some of the practice is specific to the afferent information garnered in a performance situation. Although this experiment should not be generalized to sport situations, these findings provide the basis for further research on the beneficial effects that variability of practice can have on minimizing performance decrements because of the specificity of learning effect.

Conclusions

The results of this study clearly argue in favor of the idea that the specificity of learning effect has its limits and that variability of practice can limit performance decrements. In essence, only a limited amount of variability is necessary (in this study 25% and as little as 12.5%) to overcome the specificity of learning effect. These results imply that the strong sensorimotor representation that leads to the specificity of learning effect could not be built up due to the variability added in this experiment. This outcome has positive implications for coaches, athletes, educators and anyone who is involved in designing effective practice. Although further research involving other tasks and practice situations is necessary to be able to generalize these results, the decreases in accuracy caused by the specificity of learning effect appear to be remedied by making a limited amount of the afferent information present in performance (i.e. 25%) available during practice.

CHAPTER 4
VISION: WHAT ASPECT OF VISION IS RESPONSIBLE FOR THE SPECIFICITY OF LEARNING EFFECT

Introduction

Dual Visual System

Paillard (1980; Paillard & Amblard, 1985) suggested that there are two different visual channels: one kinetic and one static. The static channel would be best suited for the processing of slow visual information taking place in central vision, which is usually the case when the hand approaches the target in a conventional aiming task. On the other hand, the kinetic channel would be best suited for processing the high-speed visual information that might be available in the periphery of the retina. Assuming that participants normally look at the target they aim at, this kinetic channel appears to prefer the information that is visually available in the first half of an aiming movement. Support for Paillard's proposition was found consistently in a series of experiments conducted by Bard and colleagues (Bard et al., 1985; Bard et al., 1990; Blouin et al., 1993; Blouin et al., 1992).

Paillard and Amblard (1985) argued that a distinction has to be made between two independent visual channels as each processes different types of visual information. Both channels would operate in a closed-loop fashion and would provide either positional or directional error signals regarding an ongoing

aiming movement. The first system would operate in foveal vision and account for the terminal correction of the trajectory during the homing in phase of the aiming movement. The second channel would operate faster than the former and provide information regarding the directional error of the moving limb toward the target. Furthermore, this second channel would appear to be particularly effective in the initial phase. The first system which operates in central vision appears to be the most important aspect for learning as terminal accuracy is the common goal and that this central vision is most involved in the control of aiming movements (Paillard & Amblard, 1985). In light of much of the research on specificity of learning, it may be suggested that the information that is processed in central vision, is used to control movement even after extended practice. This information is used to strengthen a sensorimotor store that is relied upon during the execution of the movement (Proteau, 1992).

Results from Proteau et al. (1987), and Proteau et al. (1992) indicated that the different sources of afferent information are compared to an integrated or "intermodal" representation of the expected sensory consequences. They proposed that the integrated store gives more information than simply adding different sources of afference and leads to better performance in instances where greater amounts of practice are involved. This view leads to the conclusion that the underlying principle for skilled movement acquisition is inter-sensorimotor integration, where the available sources of sensory feedback are integrated and used in conjunction with central planning and execution processes to form the basis of movement representation.

Kinetic Vision

In numerous daily activities we must touch or grasp things that are located in our environment. To reach our goal, we can take into account numerous sources of information. This information indicates what our body position is in relation to the intended target and surrounding environment as well as the location of our hand and of the intended target in both personal and extrapersonal space. In such tasks there is wide acceptance that the "kinetic" visual information available (i.e., seeing one's hand) is an important determinant of spatial accuracy. This is because even extensive practice in a situation in which vision of the hand is not permitted does not enable one to be as accurate as when both vision of the hand and of the target to be reached are available (Proteau & Masson, 1997). The above proposition is also well supported by the fact that withdrawing vision of the participants hand after lengthy practice of a visual aiming task during which vision was available causes a severe increase in the participants spatial aiming error (Proteau, 1992).

Based on the research of Prablanc and colleagues (Prablanc et al., 1979a, b) and Carlton (1981) there is general acceptance that, contrary to Stubbs (1976) proposition, vision of the intended target coupled to kinesthetic information coming from information of the ongoing limb is not sufficient to ensure optimal aiming accuracy. Elliott (1988) showed that aiming accuracy was identical between a conventional no-vision condition and a situation in which both the ongoing stylus and the target to be reached were visually available.

Proteau and Cournoyer (1990) reasoned that the number of trials used by the researchers might have caused these discrepancies. Prablanc et al. (1979a, b) used 960 trials, and Carlton (1981) used 400 total trials while Elliott (1988) used only 14 total trials. Proteau and Cournoyer (1990) replicated these studies using 15 and 150 trials. For the first 15 trials, accuracy was similar under the vision of stylus condition and the target only condition. However, as training increased, it is also clear that the participants became more efficient in using the information provided by the luminescent stylus. These results suggested that the kinetic visual information available in an aiming task became more important for movement control as practice at the task increases. There is also a belief that what is learned during acquisition is specific to the sources of information available during that phase (Proteau & Cournoyer, 1990). However, these results are not taken as evidence that the static visual cues available in a normal visual context are of no use. First, as previously reported, Prablanc et al. (1979a, b) clearly showed that even after 960 trials of practice, vision of the surrounding environment prior to movement initiation helped the participants to be more accurate in a finger pointing task.

Further research in vision's role in motor skill by Smyth and Murray (1982), determined the role played by seeing ones hand to catch a ball. Participants were asked to catch tennis balls with one hand under normal conditions and with an opaque screen which obstructed the view of their own arm as well as the last 150-200 ms of the ball trajectory. They concluded that the ball requires the most visual attention in catching, but accurate and effective use of the

hand is increased when the hand can also be seen. Since then it has been shown that seeing ones hand is important for optimal catching accuracy, even when the period of ball occlusion is reduced to 100 ms or below (Smyth, 1982; Fischman & Schneider, 1985; Diggles, Grabiner, & Garhammer, 1987; Davids, & Stratford, 1989). In tasks that involve interceptive action, such as catching or striking a ball, the relative importance of vision is magnified (Savelsbergh, & Whiting, 1992). Successful performance depends on the participants' ability to precisely time ball arrival and, thus, his or her grasp. Savelsburgh, Whiting, and Bootsma (1991) showed the importance of Tau (time to impact) in catching. Through the use of a deflating ball, they were able to dissociate retinal expansion and ball velocity, demonstrating that adjustments in hand movement were linked to the former.

Davids, Palmer, and Savelsbergh (1989), used similar methods as above with a volleying task and found that participants performed equally well under both conditions. These results agreed with Wallace and Newell (1983) who found that the use of low indices of difficulty did not result in a better performance under a full vision than a no-vision condition, whereas more difficult tasks were shown to be more accurately performed under the full vision condition. These findings suggested that the tolerable margins of error could dictate whether or not the participant uses visual information regarding the performing limb.

In their pioneering work, Held and Bauer (1967) suggested that what is critical for the normal development of visuomotor coordination is the opportunity to correlate proprioceptive visual feedback and that it is the visual kinetic cues available while one is performing an aiming or aiming-like movement that are

main contributors to movement accuracy. This conclusion, however, may be task specific. In line with the Wallace and Newell (1983) and Davids et al. (1989) studies, it is likely that the margin of tolerable error interacts strongly with the importance of visual information for the control of an ongoing movement. As Wallace and Newell (1983) stated, when the task has a high margin of tolerable error, the task may be easy enough that vision would not have to be so heavily relied upon. If the accuracy requirements of the task are very easy to meet, one can imagine the so-called ballistic part of an aiming movement can, with sufficient practice, be fine-tuned to the point that online control is not required for the attainment of the goal. In such a situation the withdrawal of visual information would not affect performance.

Static Vision

In terms of static cues available in the environment prior to movement initiation, the literature has reported that static cues would only be beneficial very early in learning (Prablanc et al., 1979a, b). In the latter case, the static cues would thus play a major role for movement planning. Finally, static cues available immediately after movement completion would favor movement accuracy through a feedforward process because seeing your arm movement error can be used to update movement representations for a future trial (Beaubaton & Hay, 1986; Hay & Beaubaton, 1986).

Prablanc and colleagues (Prablanc et al., 1979a, b) showed that when vision of the hand was not permitted during movement, being able to see the hand and the target prior to movement enabled the individual to be more accurate than

when this information is not available. They suggested that once the start and end points were determined visually, the movement could be performed adequately in a closed loop manner under kinesthetic control by comparing proprioceptive afference and the visual goal.

Further research on static vision involving the hand by Abahnini, Proteau, and Temprado (1997), attempted to determine if vision of ones hand as it crosses the target (which normally occurs in central vision and is supposedly under the control of a slow-processing static visual channel) could be used so that directional accuracy is optimized. Concerning the existence of a kinetic visual channel, the results of the acquisition phase of their experiments indicated a lower directional error of aiming when the participants hand was visible in the visual periphery than when only the target to be crossed was visible. This result confirmed that the peripheral retina provided information that permitted the participants to optimize directional accuracy. However, the same advantage over the target-only condition was also found when the hand was visible only in central vision. Moreover, no differences in directional accuracy occurred between the peripheral and the central visual conditions.

Summary

Results of recent motor control research indicate that in many tasks, visual information remains of primary importance for optimal accuracy even after extended practice. One of the points that is yet unclear is whether it is solely the kinetic visual information about the moving limb that is important for movement control. In past aiming studies, the transition to the transfer condition involved

withdrawal of both the kinetic vision and the static visual cues available during the ongoing movement (Proteau, 1995).

It is reasonable that, with practice, an individual learns to correlate the position taken by his or her limb to the visual and kinesthetic sensory information available. Therefore, the withdrawal of the visual scene in which the movement normally unfolds could cause the severe decreases in the spatial accuracy of the participants' movements that are found after a thorough sensorimotor representation is built leading to the specificity of learning effect (Proteau, 1992; Proteau, et. al., 1992; Ivens & Marteniuk, 1997). Alternatively, one could argue that a large part of the effect was caused by postural sway resulting from visual occlusion.

Discrepancies in the Literature

A difficulty in the literature may be the definition of kinetic and static vision. Paillard and Amblard (1985) stated that the static channel would operate in foveal vision and account for the terminal correction of the trajectory during the homing-in phase of the aiming movement. The kinetic channel, operating more in the periphery, is faster and provides information regarding directional error of the moving limb toward the target and would be more accurate in the first part of the movement. This research appears to be an attempt to define and extend research on which part of a movement (first or last) is more important for control of manual aiming tasks. Crossman and Goodeve (1983) stated that seeing one's arm as it reaches the target is a valuable source of information to ensure optimal accuracy. This information plays a role as a feedforward provider and they

proposed that this information is useful to update the motor program that is thought to control the initial phase of an aiming movement. When this information is not present, this between trial updating is no longer possible and the individual must rely solely on the movement representation developed through learning which causes a decrease in accuracy.

With the work of researchers in the area (Bard et al., 1985; Bard et al., 1990; Blouin et al., 1992; Blouin et al., 1993; Carlton, 1981; Elliott, 1988; Paillard, 1980; Paillard & Amblard, 1985; Prablanc et al., 1979a, 1979b; Proteau & Cournoyer, 1990) several discrepancies have surfaced as to which part of the movement and the inherent visual component is crucial or more important for control of manual aiming. These discrepancies have been attributed to the extent of practice (Proteau & Cournoyer, 1990) and indices of difficulty (i.e. margin of tolerable error) (Wallace & Newell, 1983).

For the purposes of this second study, kinetic and static vision have been defined slightly differently. In this experiment, kinetic vision was defined as "vision of movement" (i.e. movement of the cursor on the computer screen, and vision of the arm and hand during movement) whereas static vision was defined as vision of stationary cues (i.e., vision of the target, start position, and cursor in the start position). This design should shed some light on the respective importance of kinetic and static vision in the control of manual aiming tasks.

The goal of the present experiment was to investigate the issue of the roles of kinetic and static vision in control of manual aiming. If kinetic visual information available in an aiming task becomes more important for movement

control as practice increases, then the withdrawal of that information should result in larger aiming errors as a function of practice in a transfer test in which the static visual information remains unchanged. If this were indeed the case, there would be support for the notion that the afferent information gleaned from the kinetic visual system is integral in the building of the powerful sensorimotor representation responsible for the specificity of learning effect.

Purpose and Hypotheses

This study attempts to find out which aspect of vision is more important in manual aiming and responsible for the specificity of learning effect. The experiment had four groups: two undergoing 40 trials each (moderate practice) and two undergoing 200 trials each (extensive practice). The two levels of practice (moderate and extensive) were added to determine if the level of practice affects the role of vision in performing an aiming task. One group from each of these practice levels completed the task with kinetic and static vision (kinetic + static) while the other had only static vision. Results from this experiment should help us determine whether kinetic visual information is at least partially responsible for the specificity of learning effect with respect to vision in manual aiming tasks.

This experiment was expected to reveal that it is the kinetic visual information during a manual aiming task that causes of the specificity of learning effect with respect to vision. This hypothesis was based on previous research that has found kinetic visual information to be more important for accuracy in manual

aiming tasks when compared to static vision depending on the temporal constraints.

This study attempted to examine kinetic vision's role as a determinant of the specificity of learning effect. The results are important for coaches, trainers, and teachers or anyone involved with the scheduling of practice for motor skill acquisition, as they will be able to better design practice with respect to specific visual information to optimize performance. The information gleaned from this experiment can also be of use to motor control theorists, as they will be closer to being able to model the specificity of learning effect and predict the effects on performance in various situations.

Method

Participants

Forty right-handed participants (Oldfield, 1971) volunteered from the University of North Dakota (mean age 20.59; 23 males and 17 females). All participants' read and signed informed consent, and received no compensation. None of the participants were familiar with either the experiment or the concepts being tested. All participants had normal or corrected to normal vision.

Apparatus

Participants sat on a chair facing a computer monitor (Gateway EV700 17 inch monitor powered by a Gateway E3200 computer) and a 30.48 cm x 30.48 cm graphics tablet (Summagraphics SummaSketch III). The monitor was located 1 m above the floor on a desk. The graphics tablet was placed on a level surface

directly in front and 15 cm below, the monitor, which allowed the participant to comfortably rest the forearm on the tablet surface (see Figure 3, pg. 54).

The participant held a mouse (SummaSketch 4-button mouse) with the right hand and made all movements on the graphics tablet with this mouse. At the anterior end of the mouse there was a clear plastic pointer, which had a 5 cm diameter circular indentation with two wires intersecting and forming a crosshair within the circle. The coordinates of the crosshair intersection on the tablet surface were translated by the graphics tablet and computer as the location of the cursor. The mouse was held with the tip of the index finger placed in the crosshair (see Figure 4, pg. 55).

The location of the finger (crosshair) was translated into the coordinates of the cursor on the monitor by the graphics tablet and aiming program. The translation was performed using unity gain, which meant that a 1 mm displacement of the mouse crosshair resulted in a 1 mm displacement of the cursor on the monitor. The cursor appeared as a blue solid circle 2 mm in diameter. The output information from the graphics tablet was sent to the computer and sampled at a rate of 121.5 Hz.

As with the previous experiment, the two measures of interest were movement time and movement accuracy. Having the participants' movement times fall within a bandwidth of 375 ms – 425 ms was to control for the movement time and the speed-accuracy trade-off (Fitts, 1954). This time restriction placed conflicting demands on participants. Based on pilot studies, participants could not maintain a high level of accuracy without slowing the

movement time down to a level outside of the prescribed bandwidth. Movement accuracy was analyzed after computing radial error derived from error on the x and y-axis as specified by Hancock, Butler, and Fischman (1994).

Procedure

The independent variable was the vision condition (kinetic + static vs. static only). The kinetic + static visual condition was active when the participants had all aspects of vision at their disposal and the static only condition was when there was no kinetic vision available. Kinetic vision was withheld in two ways during static trials. First, the vision of the cursor was taken away once the target appeared, and second, vision of the hand and arm was denied by placing a black cloth over the tablet area. Participants were first given an instruction sheet to read, which provided the information needed to complete the experiment. Verbal descriptions of the trials and how to complete them were also provided.

Participants were seated in front of the graphics tablet with their midline aligned with the monitor. This position allowed the movements of the right arm to be made comfortably, as the participants sat close enough to the tablet so that the reaching movements did not require full extension of the arm.

Each trial began with a display of the mouse-cursor and the home circle or starting position. The home circle consisted of a 4 mm diameter red circle, and was located centrally at the bottom of the monitor display. This starting position corresponded to a central location approximately 8 cm from the bottom edge of the tablet's active area.

In the kinetic + static visual condition, once the home circle and cursor appeared on the monitor, the participant moved the cursor to the center of the home circle. Following the appearance of the home circle and cursor, a circular target (2 mm in diameter) appeared 13 cm from the center of the home circle. In the static only condition, the cursor was seen only in the home circle and once the movement stopped but at no time during the movement.

A tone signaled the commencement of the trial. At this point, the cursor was turned off in the static vision only condition, and kept on for the kinetic + static vision condition. When the start signal sounded the participant attempted to move the cursor to the target within a movement time of 400 +/- 25 ms. The timer stopped once the movement was complete and the x and y coordinates where the cursor movement ended, with respect to the target, were recorded.

The task was to move the stylus from the starting point to the target as accurately as possible within the 400 +/- 25 ms bandwidth. These movements were made at the midline, directly forward and away from the participant's body with the right hand. Five practice trials were allowed before the actual testing began. The participants were instructed to keep their limb motionless at the end of the movement until the feedback display appeared. The feedback display showed the home circle, and the initial position of the cursor, the target, as well as a trace of the path and the final position of the cursor. The display also showed reaction time (although not used in the analysis), movement time, and the error (in mm) in the x and y coordinates with respect to the target. Thus, during the acquisition, participants received knowledge of results about movement error on every trial.

Participants were also randomly assigned to one of four experimental groups described below.

Conditions

The experiment took place in a single session divided into three phases: acquisition, retention, and transfer. The acquisition phase was made up of either 40 or 200 trials, and the retention and transfer phases were made up of 20 trials each. The two levels of acquisition were chosen to determine whether the role played by kinetic vision changes from modest practice to more extensive practice as suggested by Paillard (1980; Paillard & Amblard, 1985). Two groups practiced the task for 40 trials; the remaining two practiced the task for 200 trials. The retention phase consisted of the same visual information as in acquisition, only without the benefit of KR or verbal feedback. In the transfer phase, both the kinetic + static, and static only groups performed the task in the opposite manner in which they were learned with respect to the visual information available, and again KR and verbal feedback were not available.

Analyses

There were five objectives to the analyses conducted in this experiment each on building upon the previous one. First, the movement times were checked to confirm that the movements were all performed within the prescribed bandwidth (400 ms +/- 25 ms) to control for the speed-accuracy trade-off relationship. Second, the presence of a learning effect was confirmed by analyzing the amount of error across blocks. If the error scores gradually decreased over time, then the learning effect would be substantiated. Third, the

mean error in the final block of acquisition (block 10) was compared to the retention test (block 11) to determine the effects of removing feedback. Checking error scores when feedback is removed will further confirm if a learning effect is present. The fourth objective was to compare mean error in the last block of acquisition (block 10) to the transfer test (block 12) to determine if the specificity of learning effect was present in any of the four conditions. This analysis is crucial to the final objective because not only does it replicate the specificity of learning effect, it provides the basis for determining which aspect of vision is most important in this phenomenon. The final objective was to analyze the error in the acquisition, retention, and transfer phases to evaluate any differences between the four condition groups to see if the amount of practice or visual conditions (dynamic + static or static only) made a difference in performance of the manual aiming tasks and the specificity of learning effect.

Results

Speed-Accuracy Trade off

Movement times were analyzed to confirm that all movements were performed within the prescribed movement times (.375 to .425 ms). Unlike Experiment 1, the number of participants in the first and last of the 10 acquisition blocks was 40, but all other acquisition blocks (2-9) had 20 participants. Table 4 contains the means, standard deviations and ranges for all blocks.

A 2 Condition (Kinetic + Static and Static Vision) x 2 Practice Level (200 and 40 trials) X 4 Phase (First and Last Blocks of Acquisition, Retention and

Table 4.
Mean Movement Times

Block #	Mean MT	SD	Min	Max
1 Kinetic A	.410	.019	.367	.437
Kinetic B	.412	.019	.376	.449
Static A	.420	.023	.397	.456
Static B	.412	.028	.375	.472
2 Kinetic A	.410	.025	.365	.444
Static A	.422	.048	.361	.498
3 Kinetic A	.403	.035	.328	.436
Static A	.413	.025	.375	.446
4 Kinetic A	.416	.032	.369	.464
Static A	.406	.027	.372	.467
5 Kinetic A	.414	.025	.377	.456
Static A	.402	.024	.370	.439
6 Kinetic A	.418	.022	.372	.446
Static A	.412	.025	.375	.450
7 Kinetic A	.426	.026	.392	.470
Static A	.403	.022	.367	.430
8 Kinetic A	.420	.022	.391	.452
Static A	.406	.020	.375	.441
9 Kinetic A	.413	.013	.395	.435
Static A	.386	.024	.359	.424
10 Kinetic A	.401	.021	.374	.440
Kinetic B	.416	.014	.383	.438
Static A	.397	.021	.359	.427
Static B	.407	.029	.370	.455
Ret. Kinetic A	.413	.017	.377	.440
Kinetic B	.417	.016	.400	.446
Static A	.402	.018	.368	.419
Static B	.422	.050	.372	.539
Tran. Kinetic A	.419	.025	.392	.461
Kinetic B	.398	.029	.372	.463
Static A	.458	.042	.353	.495
Static B	.467	.039	.428	.554

Note: $\underline{n} = 40$ for blocks 1, 10, retention and transfer, $\underline{n} = 20$ for blocks 2-9.
Note: All "A" groups performed 200 trials in acquisition while "B" groups completed 40.

Transfer) mixed design ANOVA with repeated measures on the last factor indicated that there were significant differences for the condition groups, $F(1, 36) = 28.85$, $p < .01$. Examination of Table 4 shows that all movement time means in acquisition and retention were within the prescribed range. Table 4 also shows that the static only groups (for both moderate and extensive practice) did not stay within the prescribed movement window during the transfer test. It appears that the addition of kinetic information during the transfer test caused the static only groups to perform the task more slowly, which could conceivably lead to increased accuracy due to a speed-accuracy trade-off.

Learning Effect

A 2 (Condition) X 2 (Practice Level) X 2 (Acquisition Block) mixed design ANOVA with repeated measures on the last factor, was used to confirm the existence of a learning effect, or performance improvement over practice, and to see if there were any differences between groups during acquisition. Means, standard deviations, and ranges for error scores are also included in Table 5.

Table 5.
Mean Error (Early to Late Acquisition)

Block #	Mean Error	SD	Min	Max
1 Kinetic A	13.42	3.50	9.84	18.43
Kinetic B	14.52	4.14	7.42	21.72
Static A	17.14	3.38	13.53	22.37
Static B	19.72	5.72	10.64	28.84
10 Kinetic A	8.03	2.04	5.71	12.77
Kinetic B	11.31	3.99	7.19	19.88
Static A	10.79	1.39	8.87	12.95
Static B	14.55	4.06	9.05	23.37

Note: All "A" groups performed 200 trials in acquisition while "B" groups completed 40.

The ANOVA revealed a significant effect for condition, F (1,36) = 13.20, $p < .01$, for practice level, F (1,36) = 6.81, $p < .05$, and for time (first block to last block of acquisition), F (1,36) = 72.07, $p < .01$. No significant interactions were identified, F (1,36) = .23, $p > .05$.

A Tukey's follow-up procedure revealed that for time, all conditions noted above improved from the first block of acquisition to the last block. The significance levels for the groups were as follows: kinetic + static (200 trials) $p < .01$, kinetic + static (40 trials) $p < .10$, static (200 trials) $p < .01$, and static (40 trials) $p < .05$. In each case, participants in the four conditions improved over time, which indicates the existence of a learning effect.

A separate ANOVA showed that the kinetic + static groups performed more accurately in the first acquisition block, F (1,36) = 10.74, $p < .01$ and in the final acquisition block, F (1,36) = 7.24, $p < .05$. These results show that greater learning occurs when kinetic visual information is available as opposed to when only static visual information is available. To find out the effect of the number of practice trials on performance, a second separate ANOVA was conducted and revealed that the groups practicing for 200 trials performed more accurately in the final acquisition block, F (1,36) = 10.74, $p < .01$ but not the first acquisition block, F (1,36) = 1.48, $p > .05$. This result indicates that the groups that had more acquisition trials performed better. One reason the existence of the learning effect was checked for is to satisfy a requirement for the specificity of learning effect to appear.

Retention

The three factor mixed design ANOVA, 2 (Condition) X 2 (Practice Level) X 2 (Acquisition and Retention) with repeated measures on the last factor was conducted to determine if there were any effects of removing feedback from the task and to again test how well participants in the different conditions learned the task. No significant differences were found for block, $F(1,36) = 3.88$, $p = .057$ indicating that taking away feedback did not affect aiming accuracy after acquisition. Table 6 shows the means, standard deviation, and range for the final acquisition block and retention block.

Table 6.
Mean Error (Late Acquisition to Retention)

Block #	Mean Error	SD	Min	Max
10 Kinetic A	8.03	2.04	5.71	12.77
Kinetic B	11.31	3.99	7.19	19.88
Static A	10.79	1.39	8.87	12.95
Static B	14.55	4.06	9.05	23.37
Ret Kinetic A	8.01	1.39	6.17	10.35
Kinetic B	12.00	4.85	6.27	19.76
Static A	11.09	1.86	6.90	13.15
Static B	16.90	4.56	9.22	22.52

Note: All "A" groups performed 200 trials in acquisition while "B" groups completed 40.

There were no significant interactions but the main effect for condition reached significance, $F(1,36) = 3.16$, $p < .05$ as did the main effect for level of practice, $F(1,36) = 19.08$, $p < .01$. The condition difference and level of practice difference for the final acquisition block was discussed in the previous section.

An independent ANOVA revealed that the kinetic + static groups again performed better than the static groups, $F(1,36) = 8.67$, $p < .01$. This again shows that participants performed with greater accuracy when kinetic visual information was available. The separate ANOVA for level of practice indicated that groups that had 200 acquisition trials performed much better than groups with only 40 acquisition trials, $F(1,36) = 14.78$, $p < .01$.

Specificity of Learning Effect and Effects of Kinetic Vision

A mixed design ANOVA similar to the previous sections using the final block of acquisition and the transfer block revealed a significant condition effect, $F(1,36) = 4.11$, $p < .05$, block effect, $F(1,36) = 11.77$, $p < .01$, practice level effect, $F(1,36) = 5.66$, $p < .01$, as well as a significant interactions of condition by block, $F(1,36) = 82.16$, $p < .01$ and practice level by block, $F(1,36) = 9.15$, $p < .01$. Means, standard deviations, and ranges for all groups during acquisition and transfer are presented in Table 7.

Table 7.
Mean Error (Late Acquisition to Transfer)

Block #	Mean Error	SD	Min	Max
Kinetic A	8.03	2.04	5.71	12.77
Kinetic B	11.31	3.99	7.19	19.88
Static A	10.79	1.39	8.87	12.95
Static B	14.55	4.06	9.05	23.37
Tran Kinetic A	15.36	2.51	11.18	20.08
Kinetic B	16.85	4.31	12.69	24.45
Static A	10.10	2.66	5.16	13.67
Static B	9.43	2.19	5.16	13.86

Note: All "A" groups performed 200 trails in acquisition while "B" groups completed 40.

The condition and level of practice main effects for the final acquisition block were described previously. A separate ANOVA revealed a significant condition effect in the transfer block $\underline{F}$ (1,36) = 44.21, $\underline{p} < .01$ which indicated that the kinetic + static groups performed with less accuracy than the static groups. This result shows that when the two groups performed in visual conditions they were not familiar with, the static groups aimed with greater accuracy. No differences between practice levels were found in the transfer block $\underline{F}$ (1,36) = .08, $\underline{p} > .05$.

The significant interactions were interpreted by looking at the simple main effect tests described above as well as using Table 7 and Figure 7.

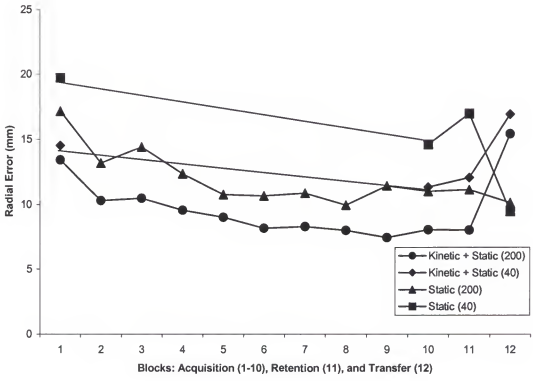

Figure 7. Mean radial error for static and kinetic + static vision.

The practice level by block interaction indicates that the participants with only 40 acquisition trials performed with greater accuracy than the ones with 200 trials. This finding is due to the transfer condition causing an overall decrease in accuracy for the 200 trial groups while the 40 trial groups suffered no such decrease. The significant condition by block interaction indicates that the kinetic + static groups suffered a decrease in accuracy whereas the static groups improved. These results clearly indicate the existence of the specificity of learning effect for the kinetic + static group but not the static group.

Discussion

The purpose of this experiment was to determine the role that kinetic vision plays in learning manual aiming tasks and in the specificity of learning effect. The five objectives of the experiment are discussed below.

Speed-Accuracy Trade off

As hypothesized, participants performed the task within the prescribed movement time in acquisition and retention. What was not predicted however, was kinetic vision's effect on performance in transfer when it was previously absent. Adding kinetic vision to the task for groups that practiced with only static vision caused a significant increase in movement time. Although movement times were only outside of the specified window by 34 ms and 43 ms respectively for the static (200) group and static (40) group, this additional time may have been enough to cause a speed-accuracy trade-off and possibly confound the error scores in transfer. Apparently, being able to see movement of the cursor and the hand and arm caused participants in the static groups to take more time to

complete the task. This result may have been due to additional on-line processing time being required to deal with the additional visual information.

Learning Effect

Three findings were reported significant that contribute to the conclusions about the learning effect. As hypothesized, the groups that had the benefit of more trials performed better than those that did not. The kinetic + static groups performed better than the static groups over acquisition, which was also expected. Kinetic vision appears to be extremely important to learning manual aiming skills and that the same level of performance cannot be attained without the benefit of this type of visual information (at least for 200 trials).

An important point to note is that participants in all groups were able to see during the entire experiment and that the only difference between the vision groups was the visual information with respect to motion. This format is unlike several similar manual aiming studies that used visual occlusion methods or employed a "lights off" strategy (Davids & Stratford, 1989; Diggles et. al., 1987; Elliott, 1988; Fischman & Schneider, 1985; Prablanc et. al., 1979a, 1979b; Proteau & Mason, 1997; Smyth & Murray, 1982). This effectively controlled for any confound that may have occurred due to postural sway when vision was taken away. Thus, vision of motion appears to play a key role in learning manual aiming skills.

The final point with respect to learning in acquisition that was found was that all groups improved over time and that a learning effect was evident. To demonstrate the existence of a learning effect, participants had to show significant

improvement in performance over time as learning is a relatively permanent change in performance independent of KR (Salmoni et. al., 1984). This result sets the stage for the specificity of learning effect to appear which was of primary interest in this study.

Retention

As hypothesized, the results with respect to learning in acquisition were confirmed in retention. Again, the groups with kinetic information performed with greater accuracy and the groups that had 200 acquisition trials performed more accurately than groups that had only 40 trials. The difference in retention is that feedback is taken away for all groups. Although there were no significant differences from acquisition to retention, what can be seen is that most participants performed the task with slightly more error, which is typical of manual aiming studies.

The Specificity of Learning Effect and the Effects of Kinetic Vision

The transfer test offers some interesting and relevant information regarding kinetic vision and the specificity of learning effect. The importance of kinetic vision is again emphasized by the fact that when this information was removed during the transfer phase, the groups performed with less accuracy. The other factor that needed to be present to show kinetic vision's importance to performance in manual aiming was also found. This result is consistent with literature to date on the importance of kinetic vision in manual aiming tasks (Carlton, 1981; Elliott, 1988; Proteau, 1992; Proteau & Masson, 1997; Proteau et. al. 1992). When kinetic vision was added during the transfer phase to the static

only groups, the new visual input caused decreases in error. Together, results indicate that kinetic vision (vision of movement during the task) appears to be the driving force behind performance in manual aiming tasks. This idea is consistent with Abahnini, Proteau, and Temprado (1997) who found that vision of the hand in either the first or last half of an aiming movement was more important than a target-only condition. The results also support Proteau and Cournoyer (1990) who stated that kinetic vision becomes more important with increased practice. Now that the importance of kinetic vision has been established in manual aiming, we turn to the specificity of learning effect.

Typical of specificity of learning studies, the results revealed that when participants had extensive practice with full vision, a marked decrease in accuracy was observed when an aspect of visual information was withheld (in this case kinetic vision). This result supports previous studies that showed performance decrements when visual afference in performance conditions were different from conditions in acquisition (Ivens & Marteniuk, 1997; Proteau, 1992; Proteau & Cournoyer, 1990; Proteau et. al., 1987, 1992).

However, contrary to previous studies mentioned above, when a specific aspect of visual afference was added in transfer where it was not previously present in acquisition, there were no decrements in performance. In fact, mean error scores for the static groups with 200 trials (typically more than enough trials to elicit the specificity of learning effect) actually improved slightly when compared to the final block of acquisition and the retention block. The results of this study can be interpreted as kinetic vision playing a major role not only in the

performance of manual aiming tasks but in the specificity of learning effect as well.

As previously mentioned, there may have been a slight speed-accuracy trade-off during transfer which could be construed as a confound in the error results. If the participants moved slowly with the intent of being more accurate, then validity of the error measures would be compromised. The two static groups (200 and 40 trials) performed the aiming task slower during the transfer phase. What could be argued is that the additional time taken to complete the task that helped the participants to perform with greater accuracy and therefore negate the specificity of learning effect. Alternatively the argument exists that the addition of kinetic visual information caused the increase in movement time because of the greater amount of time needed to process the additional information and the specificity of learning effect's failure to appear. Proteau and colleagues (Proteau et. al., 1992) stated that adding vision probably resulted in participants attending to that information and neglecting the basis on which the task was learned because of its dominance as a source of information. Although staying within the prescribed movement time (375-425 ms) was emphasized over accuracy to control for just such an occurrence, there appeared to be an additional processing load when kinetic vision was added, which was too powerful to overcome. However the emphasis on staying within the movement time window increases the likelihood of the second proposition (that extra time was needed to process the additional kinetic visual information that caused the movement times to be

slower) being more accurate. Further research is required to substantiate the present findings and provide stricter control for movement time.

Conclusions

The present findings revealed that kinetic vision plays an important role in manual aiming as evidenced by superior performance in acquisition and retention by groups with that information at their disposal. Kinetic vision appears to play an important role in the well-known specificity of learning effect as well. The removal of kinetic vision caused a powerful appearance of the specificity of learning effect whereas the addition of kinetic visual information did not. Also discovered was that the addition of kinetic vision caused participants to move slower which may have led to a speed-accuracy trade-off or to a further emphasis on the importance of kinetic visual information and the effect this information has on perception and performance.

The results of this study have implications for the planning of practice and modeling of the specificity of learning effect. Kinetic vision is important in learning as well as in the specificity of learning effect. This importance of kinetic vision indicates that when designing practice, special attention should be given to kinetic visual cues that are present in performance conditions. The kinetic visual cues available in performance need to be present in practice for effective learning to take place. With respect to modeling the specificity of learning effect and defining the effect's limits, kinetic vision plays an important role. Further research is necessary to give us a better understanding of this phenomenon and the role that kinetic vision plays in the specificity of learning effect.

General Discussion

The two experiments in this study had two specific goals; (a) testing the limits of the specificity of learning hypothesis and (b) to further our knowledge on the specificity of learning effect by determining the role of kinetic vision in this phenomenon. The two experiments had similar goals in that several objectives had to be met before the eventual goals of the study could be explored. The possibility of a speed-accuracy trade-off confound had to be eliminated so that a learning effect could be reliably discovered if present. In both experiments, the participants stayed within the prescribed movement time bandwidth. Also important was the replication of previous experiments to establish the presence of a learning effect. The learning effect is an important basis of the specificity of learning effect. A task must first be well learned for a change in afferent information to elicit the specificity of learning effect. As hypothesized in both experiments, the learning effect was established which allowed the focus of the analysis to be turned to the specificity of learning effect. To fully explore the specificity of learning effect and test it's limits, there was an importance to replicate the effect from both a non-vision to vision transfer, and a vision to non-vision transfer.

The first experiment effectively tested the limits of the specificity of learning effect by adding groups with 25% and 12.5% variability to the traditional vision and non-vision groups in a transfer paradigm. Variability turned out to have a profound effect on the specificity of learning effect as 25% variability was found to be enough to negate the effect for the vision transfer and only 12.5%

variability was needed in the non-vision transfer. In essence, the results of this experiment have shown that the specificity of learning effect is not so strong that a very limited amount of variability would not be able to negate the decrements in performance, at least with respect to manual aiming tasks. The results agreed with the hypothesis that variability of practice would effectively counter the negative result on performance that the specificity of learning effect has been known to cause.

The second experiment furthered our knowledge on the specificity of learning effect by determining the role that kinetic vision (vision of motion) plays in this phenomenon. By checking movement time for the speed accuracy trade-off and determining the existence of the learning effect and the specificity of learning effect as in the first experiment, we could focus on the effects of kinetic and static vision in the transfer paradigm. The reasoning behind this experiment was that if kinetic visual information becomes more important for movement control as practice increases, then the withdrawal of that information would result in larger aiming errors as a function of practice (hence the 40 and 200 trial acquisition groups). This increase in aiming error would occur in the transfer test in which the static visual information remained unchanged. If this were the case it would support the notion that the afferent information gleaned from the kinetic visual system is integral in the building of the sensorimotor representation responsible for the specificity of learning effect (Proteau et al., 1987; Proteau et al., 1992).

In this study, the adding and removing of dynamic vision had a profound effect on performance, which firmly establishes it as a crucial aspect of manual

aiming tasks. The removal of kinetic vision caused decreases in performance and the addition of kinetic vision improved performance actually superceding the specificity of learning effect in these cases. Typically, performance on a task learned with specific afferent information present in the acquisition period would suffer when faced with a transfer task containing a different set of afferent information (i.e. vision). In this case, adding kinetic vision to a transfer test when only static vision was previously present resulted in no such decreases in performance. The results of Experiment 1 are significant in several ways. The knowledge of the specificity of learning effect has been added to as we now know that only a limited amount of variability in necessary to overcome the powerful influence on performance. The practical implications include using this information to design better practice. If variability is added during practice sessions, we can insure that performance will not be compromised by the specificity of learning effect. Kinetic vision (the vision of movement) appears to be a key ingredient in the specificity of learning effect and in motor skill learning in general and only further research into the area will reveal just how important it is.

All of the hypotheses posited in this study have been supported. There was a specific progression of hypotheses that built upon each other. Participants stayed within prescribed movement times as expected, which led to the hypothesis that a learning effect would be found. The learning effect was confirmed which was important as the learning of a task under specific afferent conditions is what leads to the specificity of learning effect. The purpose of this dissertation and the

common theme that ties them together was to help define the limits of the specificity of learning effect with respect to variability and determine the limits and causes of the effect with respect to kinetic and static vision. The hypothesis that variability would be capable of overcoming the specificity of learning effect was upheld as well as the hypothesis that kinetic vision would be a powerful influence over the specificity of learning effect and in manual aiming in general.

A surprising finding was the tendency of participants to take longer to complete a manual aiming task when kinetic vision was added in a transfer phase when this visual information was unavailable during the acquisition phase. Although this finding could be misconstrued as a speed-accuracy trade-off confound, a more likely explanation is that the addition of this visual information was so overwhelming that it took more time to process and use during the task. Therefore, this increase in on-line processing time proides further proof that kinetic vision is an integral component of manual aiming tasks.

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APPENDIX A
EQUIPMENT SPECIFICATIONS

Computer Specifications

Gateway E-3200 System

Summary:	Supports Pentium II microprocessors operating at 233 MHz to 333 MHz with 66 MHz FSB and 350 MHz to 450 MHz with 100 MHz FSB. Features NLX form factor.
Case:	15" x 17.5" x 4.7" (WxDxH)
Processor:	Intel Pentium II with MMX technology
Processor Speed:	233 MHz, 266 MHz, 300 MHz, 333 MHz, 350 MHz, 400 MHz, and 450 MHz
Cache Subsystem:	Primary, 32 K write-back cache; 16 K code/16 K data. L2 cache is integrated into the Pentium II processor cartridge with both 256 K and 512 K configuration (four-way set associative).
RAM capacity:	168-pin Sync DRAM (SDRAM) memory. Three slots. Expandable to 384 MB SDRAM.
BIOS:	Phoenix BIOS. Flash BIOS for easy updates from diskette.
IDE interfaces:	Supports up to four IDE devices (hard disks or CD-ROMs) using two PCI IDE connectors on riser card. Automatic drive type selection for easy setup.
Diskette drive:	A floppy controller is integrated on the system board. Support available for primary and secondary diskette drives or tape backup unit.
I/O ports:	One parallel and two serial ports on system board. LPT and COM configurable from system setup program. No jumper settings required.

USB:	Universal Serial Bus (two ports)
Mouse:	PS/2 mouse connector
Keyboard:	PS/2 keyboard connector
AGP expansion slot:	One slot (dedicated graphics/video)
On-board AGP:	ATI RAGE PRO TURBO integrated 64-bit AGP graphics accelerator.
Shared PCI/ISA Expansion slot:	One PCI and one ISA slot are shared
PCI expansion slots:	Two
Network:	10/100 Mbit per second Ethernet network support
Power Supply:	145 watts. ATX power connector for easy power cable changeover.
System environment:	Internal temperature: 10 C to 35 C Humidity: 20% to 80% Altitude: -200 ft to 10,000 ft Shock, Vibration: 12 g, 11 ms half-sine, 2 to 200 Hz, 0.25 g sinusoidal Processor clearance: >.4 inch after installation, top and sides
Certification:	FCC Class B, UL, CUL, CE Mark, VCCI Class B, CB Scheme

Monitor Specifications

Gateway EV700 Monitor

CRT:	17-inch diagonal (15.9 inches) flat square tube, antistatic, 90 degree deflection, .28 mm dot pitch
Resolution:	1280 x 1024
Display colors:	Unlimited
Scanning Frequency:	Horizontal, 30-70 kHz Vertical, 160 Hz
Display area:	325 x 244 mm (WxH)

Power input:	90-264 VAC, 50/60 Hz, 2.0 A
Dimensions:	415 x 430 x 459 mm (WxHxD)
Weight:	17.0 kg
Certifications:	UL, CSA, DHHS, FCC Class B, MPR-11, CE Mark, TCO-92, Energy 2000
Power Management:	Meets International ENERGY STAR requirements: Suspend mode= <15 W Active-off mode=<3 W

Graphics Tablet Specifications

Summagraphics SummaSketch III digitizing graphics tablet

Size:	12 x 12 inch digitizer
Resolution:	2,540 lines per inch/ 100 lines per millimeter
Data Rate:	up to 150 reports per second
Technology:	electromagnetic
Proximity:	0.5 in/12.7 mm
Accuracy:	.010 in/.254 mm
Platform support:	Compatible with over 400 software programs, including Windows 3.1, 95, NT, AutoCAD
Software Drivers:	ADI, Microsoft Windows 3.1, 95, NT drivers, Tablem.com with Microsoft Mouse Emulation
Transducer options:	4-button cursor mouse
Weight:	9 lb/4 kg

Automatic tablet configuration

PC interface cable

Power supply

APPENDIX B
INFORMED CONSENT AGREEMENT

Project Title: Variability and the Specificity of Learning Hypothesis

Principal Investigators: Martin W. Short, H.B.P.E, MS, Doctoral Candidate, Department of Exercise and Sport Sciences, University of Florida, Instructor, Department of Physical Education and Exercise Science, University of North Dakota, (707) 777-9899, mshort@grove.ufl.edu

James H. Cauraugh, Ph.D., Associate Professor, Director of the Motor Behavior Laboratory, Department of Exercise and Sport Sciences, University of Florida, FLG 132-F, (352) 392-0584 ext. 273, jcaura@hhp.ufl.edu

You are being asked to participate in this study as part of an authorized research program at the University of North Dakota, under the supervision of Martin Short.

Purpose of the Research: The primary purpose of this investigation is to determine the effect of variability of practice on the specificity of learning hypothesis. Also, we will attempt to determine if kinetic vision of an aiming task is responsible for the specificity of learning hypothesis by changing kinetic vision of the task while keeping the motor component identical.

What you will be asked to do in this study: You will be seated facing a graphics tablet and monitor, close enough to the tablet so that the reaching movements will not necessitate full extension of the arm. Each trial will begin with a display of the mouse-cursor and the home circle or starting position. The home circle will consist of an 8mm diameter red circle with a central circular opening 4mm in diameter, and will be located centrally at the bottom of the monitor display. This starting position will correspond to a central location approximately 8cm from the bottom edge of the tablets active area.

Once the home circle and cursor appear on the monitor, you will move the cursor to the center of the home circle and following the appearance of he home circle and cursor, a circular target will appear 13cm from the center of the home circle.

There will be a warning signal 3 seconds before the trial is to commence. A start signal will sound and you will move the stylus to the target with a movement time of 550 +/- 50ms.

The task will be to move the stylus from the starting point to the target as accurately as possible within the 550ms bandwidth and if the movement time is outside of the bandwidth then the trial will be redone and the results will not be included in the analysis. Five practice trials will be allowed before the actual testing begins. On all trials, you will be able to see your accuracy error at the end of the trial and will be given feedback on your movement time.

You will perform 200 trials of the task with varying amounts of these trials being with full vision depending on the group that you are assigned to. The transfer task in all cases that will be used is the same task under full vision conditions.

Feel free to ask us any questions you might have about the research project and/or your rights as a volunteer participant.

Potential Risks: There is no anticipated risk or discomfort during any portion of the testing.

Potential Benefits: By going through the training sessions you may improve your fine manual aiming skill.

Randomization: The condition of practice you will be assigned to will be based upon a method of randomization. Randomization means selection of a treatment by chance. This is predetermined by a computer, and selection of treatment for each patient is done in a sequential manner. This is the equivalent to flipping a coin to select one of two treatments.

Confidentiality: Your data and answers will remain confidential to the extent provided by law. Your identity will be withheld from data files, sheets, and analyses because a number coding system will be used. Only grouped data will be reported in any future publication. The data will be retained for a period of 3 years following the completion of the study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission..

Voluntary participation: Your decision whether or not to participate will not change your future relations with the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without it being held against you.

Whom to contact if you have questions about the study: The investigators involved are available to answer any questions you have concerning this program. In addition, you are encouraged to ask any questions concerning this program that you may have in the future. Questions may be asked by calling:

Martin W. Short, H.B.P.E, MS, Doctoral Candidate, Department of Exercise and Sport Sciences, University of Florida, Instructor, Department of Physical Education and Exercise Science, University of North Dakota, (707) 777-9899, mshort@grove.ufl.edu

James H. Cauraugh, Ph.D., Associate Professor, Director of the Motor Behavior Laboratory, Department of Exercise and Sport Sciences, University of Florida, FLG 132-F, (352) 392-0584 ext. 273, jcaura@hhp.ufl.edu

You will be given a copy of this form.

Agreement: All of my questions have been answered and I am encouraged to ask any questions that II may have concerning this study in the future. I have read all of the above and willingly agree to participate in this study explained to me by Martin Short.

Participant's Signature	Date	Parent or Legal Guardian's Signature, as Applicable	Date

APPENDIX C
PARTICIPANT INFORMATION SHEET

The investigator will run you through the process involved in completing the task step by step but here are some guidelines to help.

- Sit squarely in front of the monitor and tablet and have the arm and hand in a comfortable position to move the tablet mouse
- Put your index finger in the circle at the front of the mouse and keep it there throughout the experiment
- How quickly you react when you hear the tone is not important, it is just a signal to start when you are ready
- The movement time however, is important and we ask you to complete the movement in approximately 400ms
- You will be given 5 practice trials to get a feel for the movement and timing involved with feedback from the investigator
- At the beginning of each trial you will be asked to place the cursor in the start circle. Be sure to place the cursor in the top half of the circle or else the target will not appear and the trial will have to be redone. This takes a little getting used to but the investigator will demonstrate it for you
- At the tone, a target will appear and you are required to move the cursor with the mouse in one smooth movement as close to the target as possible in 400ms
- After each trial, feedback will appear on the screen and will be interpreted for you by the investigator. The feedback will tell you how long your movement took and how close to the target you were. Tell the experimenter in one word "over" or "under" how accurate your movement time was. After the trial is complete and feedback has been given, a button will be pressed to start the next one
- There will be a total of 225 trials (5 practice, 200 training, 20 retention) and the experiment will last approximately 45 minutes
- During various trials in practice, acquisition and during the retention test, you may be required to complete the task without vision of the cursor. Perform the task as normal and move the mouse towards the target as if the cursor was there.

Thank you again for your participation in this experiment.

APPENDIX D

SAMPLE PROGRAM FOR DATA COLLECTION

Dtrack data collection program

```
# this shows the program commands while it runs (we don't need it on)
echo off
#     diss1.cmd
# this cmd file shows a target to move to
# it is the full vision condition
# 200 trials with vision
# set the comport here
comport 1
# set the sampling frequency for your setup here
sampfreq 121.5
# add this statement because it is a SummaSketch III tablet
summaiii
# specify the number of points to collect at the above sampling frequency
points 363
# set the monitor height... play with this and see what works
# monitorheight 600
# monitorwidth 800
# unless the computer is slow.. add this for increased accuracy
dowaitforretrace true
# set cursor values
cursorradius 1
cursorcolour 3
endcursorcolour 4
# make a movement/display ratio of 1 to 1
ratio 1
# identify how the trial will be saved
trialid a
trial 1
initials dat
# now the next save will store 'a001.dat'
# this will give data of the positioning at a rate of 121.5 Hz
# this will make the starting position on the screen in a reasonable position
screenxorigin 110
screenyorigin 10
# specify the colour of the cursor
```

```
startcirclecolour 2
# this origin gets the start about in the middle of the tablet
tabletxorigin  130
tabletyorigin  120
# this will make the crosshair appear in the middle of the
# movement space if you want the subject to focus on something
# crosspos 300 400
# here's the two possible targets we don't need target 2 (commented out)
targetposition 1 0 140
# targetposition 2 0 160
# set other target values
targetradius 1 1
# targetradius 4 2
targetcolour 14 1
# targetcolour 14 2
# set the stagelines to the bottom of the screen (we don't need them)
stageline 1 0
stageline 2 0
# these will display a bunch of things after the trial has completed.
# if you don't want it displayed, just change the values to false.
# this will show the accuracy measurements
showaccuracy true
# this will show a trace of the path after a trial is complete
showpath true
# this will show the reaction times and movement times after a trial
showmt true
# this will show the target
showtarget true
# get the subject 3 seconds to get the cursor in the circle.
warmuptime 3
# have the trials start automatically after a short pause.
automatic 1
# now collect some trials, each time specifying the target to show
targetofinterest 1
# 1 (trial #1)
cursor on
# since we reset the stagelines to y=0, we need to specify the target
# in stage 3
stage 3 1 0
# ok, collect a trial
collect
# save it - the filename will be built from what we specified above
saveascii
# save the movements stats also.
# remember that the stats get stored to dtrack.sta, so erase the old one
# if desired.
```

```
savestats
# this will give stats on the reaction time, movement time, x and y coordinates
# as well as trial number, trial condition, and x and y ratios
# increment the trial counter
trial next
# 2
cursor on
stage 3 1 0
collect
saveascii
savestats
trial next

# 3
cursor on
stage 3 1 0
collect
saveascii
savestats
trial next

# 4
cursor on
stage 3 1 0
collect
saveascii
savestats
trial next

# 5
cursor on
stage 3 1 0
collect
saveascii
savestats
trial next
done

# note only 5 trials are shown here
```

APPENDIX E
INSTITUTIONAL REVIEW BOARD FORMS

University of Florida

UNIVERSITY OF FLORIDA INSTITUTIONAL REVIEW BOARD

1. Title of Project: Variability and the Specificity of Learning Hypothesis

2. Principal Investigators:
Martin W. Short, H.B.P.E, MS, Department of Exercise and Sport Sciences, FLG 100, (401) 885-2268, mshort@grove.ufl.edu
James H. Cauraugh, Ph.D., Associate Professor, Director of the Motor Behavior Laboratory, Department of Exercise and Sport Sciences, FLG 132-F, (352) 392-0584 ext. 273, jcaura@hhp.ufl.edu

3. Supervisors: James H. Cauraugh, Ph.D., Associate Professor, Director of the Motor Behavior Laboratory, Department of Exercise and Sport Sciences, FLG 132-F, (352) 392-0584 ext. 273, jcaura@hhp.ufl.edu

4. Dates of Proposed Project: From: 7/01/99 To: 7/01/2000

5. Source of Funding for the Project: No external funding

6. Scientific Purpose of the Investigation: The primary purpose of this investigation is to determine the effect of variability of practice on the specificity of learning hypothesis. It is our goal to determine how powerful this specificity of learning effect by adding variability to the practice schedule to see how long it takes for the effect to disappear. A secondary purpose is to determine if kinetic vision of an aiming task is responsible for the specificity of learning hypothesis by changing kinetic vision of the task while keeping the motor component identical. Although there has been much research on the specificity hypothesis, very little research has been done to determine its limits or causes.

Describe the Research Methodology in Non-Technical Language:
The participants will be 20 right handed (Oldfield, 1971) volunteers from the University of North Dakota. All participants will read and complete informed consent forms and will receive no compensation. None of the participants will be familiar with either the experiments or the notions being tested. All participants will have normal or corrected to normal vision. Participants will be seated facing

a mirror reflecting a computer monitor and a 58.5cm x 44.5cm graphics tablet (Summagraphics SummaSketch II professional MMII 1812). The monitor will be located 2m above the floor, 80cm above the mirror. The graphics tablet will be placed directly under the mirror, at a level that will allow the participant to comfortably rest the forearm horizontally on the tablet surface. The participant will hold a mouse (SummaSketch 4-button mouse) with the right hand and make all movements with the mouse. The mouse will be held with the tip of the index finger placed in the crosshair. The location of the finger (crosshair) will be translated into the coordinates of the cursor on the monitor. The cursor will appear as a blue solid circle 3mm in diameter. The output signal from the graphics tablet will be sent to the computer and will be sampled at a rate of 138.85HZ.

The two measures of interest will be movement time and movement accuracy. The movement time will be controlled for by having the participants fall within a 500ms-600ms window and movement accuracy will be analyzed after using an x and y axis.

The participant will be seated facing the graphics tablet and monitor with the midline aligned approximately with the monitor image on the mirror. This will allow the movements of the right limb to be made comfortably. The participants will sit close enough to the tablet so that the reaching movements did not necessitate full extension of the arm.

Each trial will begin with a display of the mouse-cursor and the home circle or starting position. The home circle will consist of an 8mm diameter red circle with a central circular opening 4mm in diameter, and will be located centrally at the bottom of the monitor display. This starting position will correspond to a central location approximately 8cm from the bottom edge of the tablets active area.

Once the home circle and cursor appear on the monitor, the participant will move the cursor to the center of the home circle and following the appearance of the home circle and cursor, a circular target will appear 13cm from the center of the home circle.

There will be a warning signal 3 seconds before the trial is to commence. The vision of the cursor will be appropriately controlled (vision vs. non-vision) for each trial. A start signal will sound, the target will appear, and the participant will move the stylus to the target with a movement time of 550 +/- 50ms. The timer will stop once the cursor reaches the vicinity of the target and the coordinates where the cursor stopped will be recorded.

The task will be to move the cursor from the starting point to the target as accurately as possible within the 550ms bandwidth and if the movement time is outside of the bandwidth then the trial will be redone and the results will not be included in the analysis. These movements will be made at the midline, directly away from the participant's body with the right hand. Five practice trials will be allowed before the actual testing begins. On all trials, participants will be able to see their error at the end of the trial and will be given feedback on their movement time.

A control group will perform 200 trials of the task with full vision of the cursor. There will be four experimental groups having 0, 25, 50, and 125 no-

vision trials respectively mixed in randomly with trials so that the total also equals 200 trials. There will be nine total comparisons made in this experiment. The control group will have the next 10 trials after trial numbers 0, 25, 50, and 125 used for comparison against groups with the same number of full vision trials mixed in with target only trials. The transfer task in all cases that will be used is the same task under full vision conditions.

Potential Benefits and Anticipated Risk: The potential benefits of this investigation include improvement in fine manual aiming skill.

Minimal psychological and /or physiological risks are involved in the performing of the manual aiming task. To ensure confidentiality, data sheets and files will be coded with numbers so that participant's names will not be necessary. Only mean performances will be reported in any publication. Once the data have been collected, the master sheet of participant names will be destroyed.

7. Describe How Participants will be Recruited, the Number and Age of Participants, and Proposed Compensation:

Participants (N = 10) will be recruited from the University of North Dakota. People without impaired or non-corrected vision will be asked to volunteer for testing. Participants will not be paid any money for participating.

8. Describe the Informed Consent Process. Include a Copy of the Informed Consent Document.

(See attached informed consent).

_____

Principal Investigator's Signature

_____

Principal Investigator's Signature

I approve this protocol for submission to the UFIRB:

_____

Department Chair Date

University of North Dakota

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM

FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

Please include ALL information and check ALL blanks that apply.

Principal Investigator: Martin W. Short Telephone: 777-9899 Date: 8/15/99

Address to which notice of approval should be sent:
104J 715 N 40th St., Grand Forks, ND 58203

School/College: Education & Human Development Department: PEXS

Proposed Project Dates: 9/10/99

Project Title: Variability and Specificity of Practice in Vision and Motor Control

Funding Agencies (if applicable): N/A

Type of Project (check all that apply)
_X_New Project __Continuation __Renewal _X_Dissertation or Thesis Research
__Student Research __Change in procedure for a previously approved project

Dissertation/Thesis Adviser, or Student Advisor: Dr. J. Cauraugh

If any of your subjects fall in any of the following classification,
Please indicate the classification(s)
__Minors(<18yrs) __Pregnant women __Mentally disabled __Fetuses
__Prisoners __Abortuses _X_UND Students (>18yrs)

If your project involves any human tissue, body fluids, pathological specimens, donated organs, or placental materials, check here __

If your project has been\will be submitted to another institutional review board(s), please list board(s): University of Florida Institutional Review Board
Submitted:Date: 7/5/99 _X_ Approved: Date: 8/12/99

1. Abstract: (Limit to 200 Words or less and include justification or necessity for using human subjects).

To date, there has been much research on the specificity of learning hypothesis but relatively little on its limits or causes. The purpose of this dissertation is to test the limits of this effect with regards to variability and discover how much

variability it would take to negate the deleterious effects that it has on outcome when the task is performed with different afferent conditions. Based on theory and past research, it is hypothesized that it will take a relatively limited amount of variability to alter the negative effects of specific training. The second purpose of this study is to attempt to reveal what it is about vision that causes this specificity effect. In particular, the effects of kinetic vision will be examined to determine whether it is this aspect of vision that is behind the specificity effect. Proteau and Cournoyer (1990) proposed that withdrawing or adding a significant amount of afferent information after a period of practice where it was respectively present or absent results in a deterioration of performance. This research is based on human performance of mostly manual aiming tasks and we intend to replicate and further these results.

Please Note: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. Protocol: (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subjects will be asked to complete.)

The participants will be 20 right handed (Oldfield, 1971) volunteers from the University of North Dakota. All participants will read and complete informed consent forms and will receive no compensation. None of the participants will be familiar with either the experiments or the notions being tested. All participants will have normal or corrected to normal vision. Participants will be seated facing a mirror reflecting a computer monitor and a 58.5cm x 44.5cm graphics tablet (Summagraphics SummaSketch II professional MMII 1812). The monitor will be located 2m above the floor, 80cm above the mirror. The graphics tablet will be placed directly under the mirror, at a level that will allow the participant to comfortably rest the forearm horizontally on the tablet surface. The participant will hold a mouse (SummaSketch 4-button mouse) with the right hand and make all movements with the mouse. The mouse will be held with the tip of the index finger placed in the crosshair. The location of the finger (crosshair) will be translated into the coordinates of the cursor on the monitor. The cursor will appear as a blue solid circle 3mm in diameter. The output signal from the graphics tablet will be sent to the computer and will be sampled at a rate of 138.85HZ.

The two measures of interest will be movement time and movement accuracy. The movement time will be controlled for by having the participants fall within a 500ms – 600ms window and movement accuracy will be analyzed after using an x and y axis.

The participant will be seated facing the graphics tablet and monitor with the midline aligned approximately with the monitor image on the mirror. This will allow the movements of the right limb to be made comfortably. The participants will sit close enough to the tablet so that the reaching movements did not necessitate full extension of the arm.

Each trial will begin with a display of the mouse-cursor and the home circle or starting position. The home circle will consist of an 8mm diameter red circle with a central circular opening 4mm in diameter, and will be located centrally at the bottom of the monitor display. This starting position will correspond to a central location approximately 8cm from the bottom edge of the tablets active area.

Once the home circle and cursor appear on the monitor, the participant will move the cursor to the center of the home circle and following the appearance of the home circle and cursor, a circular target will appear 13cm from the center of the home circle.

There will be a warning signal 3 seconds before the trial is to commence. The vision of the cursor will be appropriately controlled (vision vs. non-vision) for each trial. A start signal will sound, the target will appear, and the participant will move the stylus to the target with a movement time of 550 +/- 50ms. The timer will stop once the cursor reaches the vicinity of the target and the coordinates where the cursor stopped will be recorded.

The task will be to move the cursor from the starting point to the target as accurately as possible within the 550ms bandwidth and if the movement time is outside of the bandwidth then the trial will be redone and the results will not be included in the analysis. These movements will be made at the midline, directly away from the participant's body with the right hand. Five practice trials will be allowed before the actual testing begins. On all trials, participants will be able to see their error at the end of the trial and will be given feedback on their movement time.

A control group will perform 200 trials of the task with full vision of the cursor. There will be four experimental groups having 0, 25, 50, and 125 no-vision trials respectively mixed in randomly with trials so that the total also equals 200 trials. There will be nine total comparisons made in this experiment. The control group will have the next 10 trials after trial numbers 0, 25, 50, and 125 used for comparison against groups with the same number of full vision trials mixed in with target only trials. The transfer task in all cases that will be used is the same task under full vision conditions.

3. BENEFITS: (Describe the benefits to the individual or society.)

The potential benefits of this investigation include improvement in fine manual aiming skill.

4.RISKS: (Describe the risks to the subject and precautions that will be taken to

minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, debriefing procedures, etc.)

Minimal psychological and /or physiological risks are involved in the performing of the manual aiming task. To ensure confidentiality, data sheets and files will be coded with numbers so that participant's names will not be necessary. Only mean performances will be reported in any publication. Once the data have been collected, the master sheet of participant names will be destroyed.

5. CONSENT FORM: Attach a copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur. (describe where signed consent forms and data will be kept for the required 3 years, including plans for final disposition or destruction.)
Signed consent forms and data will be kept in a locked storage cabinet for the required 3 years and will be later destroyed via paper shredder and waste disposal.

6. For FULL IRB REVIEW forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For EXEMPT or EXPEDITED REVIEW forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

Signatures:
Principal Investigator: Date:
Project Director or Student Advisor: Date:

APPENDIX F

INSTITUTIONAL REVIEW BOARD LETTERS OF APPROVAL

UNIVERSITY OF FLORIDA

Institutional Review Board

98A Psychology Bldg.
PO Box 112250
Gainesville, FL 32611-2250
Phone/Fax: (3520 392-0433
E-mail: irb2@ufl.edu
http://web.ortge.ufl.edu/irb/irb02

DATE: 21-Jun-99

TO: Mr. Martin W. Short and Mr. James H. Cauraugh
100 FLG
Campus

FROM: C. Michael Levy, Chair
University of Florida
Institutional Review Board

SUBJECT: **Approval of Project #** 1999 - 456

TITLE: Variability and the Specificity of Learning Hypothesis

FUNDING: Unfunded

I am pleased to advise you that the University of Florida Institutional Review Board has recommended approval of this project. Based on its review of your protocol, the UFIRB determined that this research presents no more than minimal risk to participants. Given your protocol, it is essential that you obtain signed documentation of informed consent from each participant. Enclosed is the dated, IRB-approved informed consent to be used when recruiting participants for the research.

If you wish to make any changes to this protocol, you must disclose your plans before you implement them so that the Board can assess their impact on your project. In addition, you must report to the Board any unexpected complications arising from the project that affect your participants.

If you have not completed this project by 18-Jun-00, please telephone our office (392-0433), and we will discuss the renewal process with you.

It is important that you keep your Department Chair informed about the status of this research project.

CML:ek/js

cc: Vice President for Research
Dr. Sandra E. Moritz

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW

University of North Dakota Institutional Review Board

DATE: August 30, 1999 PROJECT NUMBER: IRB-9908-022

NAME: Martin W. Short DEPARTMENT/COLLEGE: Physical Education and Exercise Science

PROJECT TITLE: Variability and Specificity of Practice in Vision and Motor Control

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on 8-31-99 and the following action was taken:

☐ Project approved. EXPEDITED REVIEW NO. _____
Next scheduled review is on _____.

☑ Project approved. EXEMPT CATEGORY NO. 2. No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project approval **deferred. This study may not be started until final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project **denied.** (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature.

cc: Chair, Physical Education and Exercise Science

Signature of Designated IRB Member
UND's Institutional Review Board

8-31-99
Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

BIOGRAPHICAL SKETCH

Martin Wayne Short was born October 15, 1969 in Scarborough, Ontario, Canada to Wayne and Lorraine Short. He received an honours bachelour of physical education from Lakehead University in Thunder Bay, Ontario, Canada, and went on to complete a master of science degree at Auburn University in Auburn, Alabama, in exercise and sport science majoring in motor learning. His doctoral education was completed at the University of Florida in Gainesville, Florida, culminating with a Ph.D. in exercise and sport sciences majoring in motor learning. Martin is currently an assistant professor at the University of North Dakota in the Department of Exercise and Sport Science.

I certify that I have read this study and that in my opinion it conforms to acceptable standard of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James Cauraugh, Chair
Associate Professor of Exercise and Sport Science

I certify that I have read this study and that in my opinion it conforms to acceptable standard of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Milledge Murphey
Associate Professor of Exercise and Sport Science

I certify that I have read this study and that in my opinion it conforms to acceptable standard of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jeffrey Bauer
Assistant Professor of Exercise and Sport Science

I certify that I have read this study and that in my opinion it conforms to acceptable standard of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Ira Fischler
Professor of Psychology

This dissertation was submitted to the Graduate Faculty of the College of Health and Human Performance and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May 2000

Dean, College of Health and Human Performance

Winfred M. Phillips
Dean, Graduate School